



FOCUS

SCIENCE AND TECHNOLOGY

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UPLOAD YOUR BRAIN

How your
thoughts and
emotions will
create a new
kind of internet

**Radical
thinking**

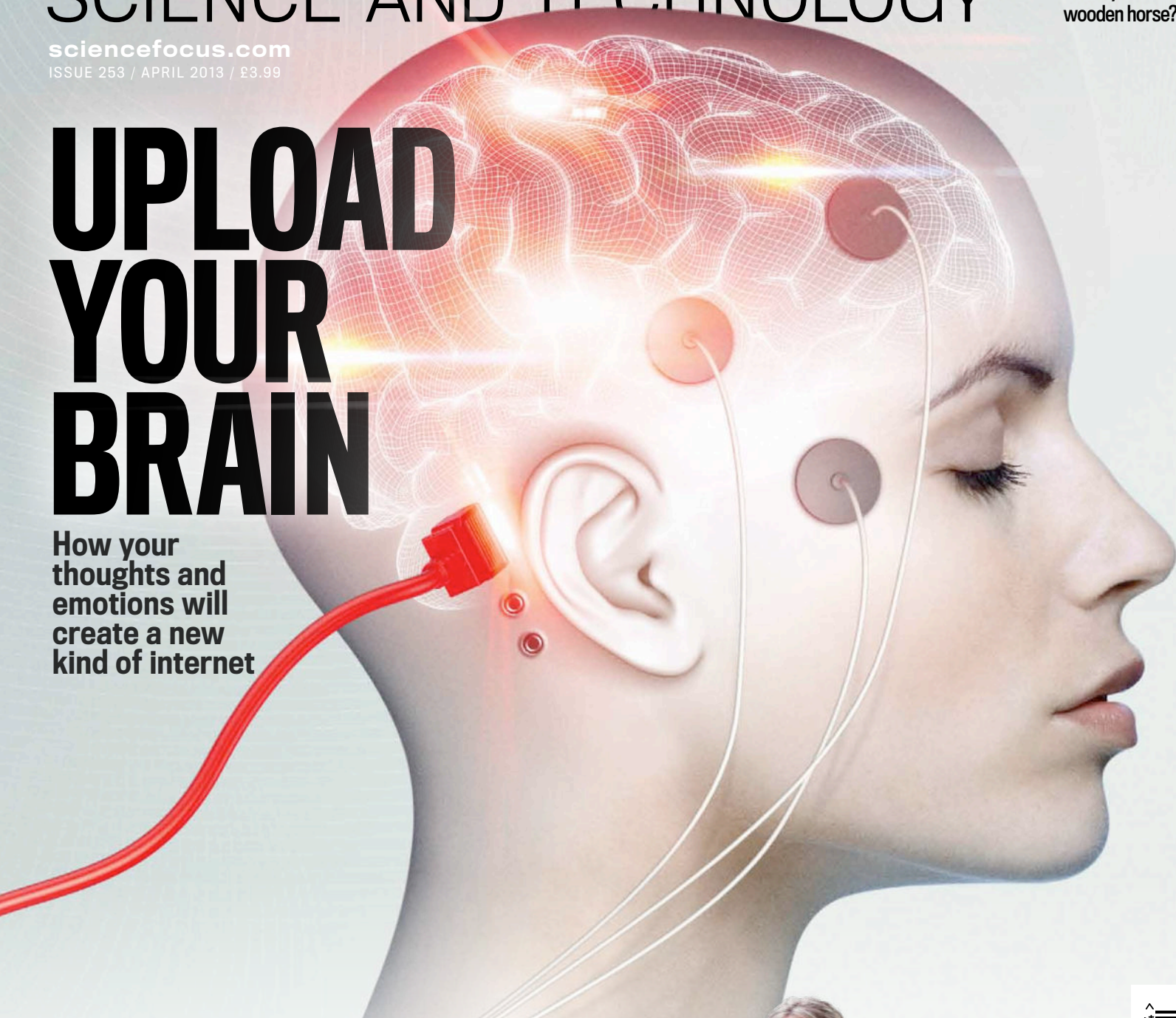
How science fiction is
creating the future

**To boldly
grow**

The veggies we'll
take to Mars

**Return
to Troy**

Will they find the
wooden horse?



CHAOS AT 50

New revelations from
the science that told
us why our weather
is so strange



Q&A

- Why does tea from plastic cups taste odd?
- Do germs have germs?
- Why isn't lightning straight?



SMART SPECS

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glasses you'll
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WELCOME TO FOCUS



IN RECENT YEARS we've spent a lot of time telling everyone what we're up to. Social networks like Facebook, Twitter and Tumblr have made it easy and fun. But what if we didn't even have to type to share memories and experiences – what if we could upload data from our brains direct to the internet? Science writer Rita Carter explores the idea on p44.

When you've read her article, let us know what you think – on Twitter, naturally!

Uploading your brain is just one idea spawned by Project Hieroglyph, which was born out of a frustration that we no longer attempt 'big things'. In the 20th century, we developed computers and nuclear energy, and went to the Moon. This year? Maybe a slimmer smartphone. We caught up with Ed Finn, who runs Project Hieroglyph, on p54.

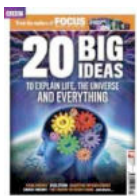
From the future to the past, and the famous city of Troy is about to be investigated once again. A team of US archaeologists is taking the latest high-tech equipment to the legendary locale to uncover its secrets, as we reveal on p56.

And finally, what can we learn from ants? Quite a lot actually, as BBC presenter Adam Hart explains on p84 – don't miss him in BBC Four's insect season *Alien Nation* later this year.

Until next issue,

Graham

Graham Southorn, Editor

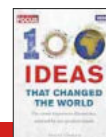


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APPEARING IN THIS ISSUE...



Rita Carter

Rita Carter is a writer, lecturer and broadcaster who specialises in the human brain – what it does, and how it does it. Her most recent book is *Mapping The Mind*. She explores the prospect of uploading our memories on p44.



Kevin Fong

An expert in space medicine, Kevin Fong lectures in physiology at University College London and is a frequent guest on BBC science shows such as *Horizon* and *Material World*. He talks to us about his new book, *Extremes*, on p118.



Adam Hart

Adam Hart is a reader in ecology and animal behaviour at the University of Gloucestershire. He's the co-presenter of the upcoming documentary *Planet Ant* on BBC Four and reveals what we can learn from the insects on p84.



Anna-Lisa Paul

Dr Paul works at the University of Florida, Gainesville, where she investigates the science of plants in space. She talks to Kelly Oakes about space gardening and why it's vital for the future of space exploration on p82.



WANT TO SUBSCRIBE?

Fill in the form on p40 and save 30 per cent off the cover price, as well as getting free access to the Focus iPad app

EXISTING SUBSCRIBERS

On p40, **Bill McGuire** discusses the threat posed by volcanoes, earthquakes and other geohazards

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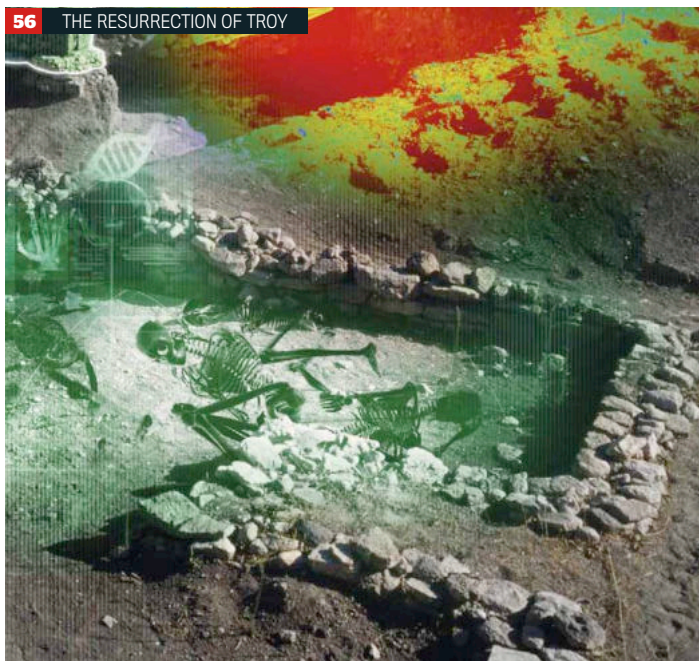
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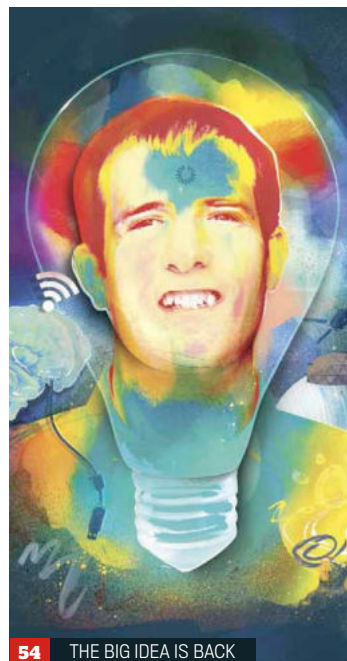
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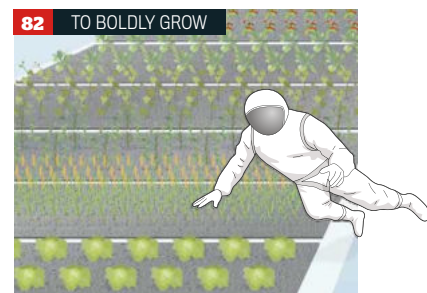
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MegaR

Google-eye view

AFTER HIKING ALONG the spectacular, Sun-dappled trails of the Grand Canyon, a Google employee pauses for breath. The contraption strapped to his back is the Trekker, Google's latest camera system. It's taking images of one of America's natural wonders that will become part of Street View, Google's online service that provides panoramic views of many places around the world.

Sitting atop the device are 15 lenses that take a 360° photo every 2.5 seconds. "The system uses GPS to record where each photo is taken," says Ed Parsons, Google's Geospatial Technologist. "It has magnetometers, gyroscopes,

and accelerometers to measure the relative movement and position the images at the right angle."

Google now plans to use its Trekker, which weighs about 18kg, to capture 360° images of many more of the world's least-accessible places, so that they too can be accessed via the Street View system. "We'd like to take it along the trails of the Amazon rainforest," says Parsons. "And we'd also like to bring it to the UK to photograph Snowdon."

The 360° views of the Grand Canyon are now live. Enjoy the magnificent panoramas for yourself at maps.google.co.uk

PHOTO: GOOGLE





MegaPixel

Winged wonder

THESE MULTICOLOURED scales don't belong to an exotic fish – they make up the wing of the Prola Beauty butterfly, *Panacea prola*, which lives in South America. The scales, seen here magnified 200 times, form part of the underside of the butterfly's forewing, where blue patches meet red.

"This flash of colour really is the most spectacular combination," says Dr David Lees, a lepidopterist at the Natural History Museum in London. The topside of the wing is less dramatic – it's black with white stripes. But when the insect is at rest, the wings' blue and red undersurfaces are visible,

serving as an advertisement to any would-be predators that this tasty-looking morsel is in fact highly poisonous.

"These butterflies tend to be slow-flying," says Lees. "Like a lot of butterflies with warning colouration, they are not afraid of predators."

The shape of the scales is common to butterflies, helping to reduce drag and keep the wing surface clean by allowing dirt to slip off easily. Research from Ohio State University in 2012 suggests that mimicking the structure of butterfly wings could help to keep medical equipment clean.

PHOTO: CHARLES KREBS/OLYMPUS





MegaPixel

Polar blooms

THIS MEADOW OF floating 'frost flowers' stretching as far as the eye can see isn't a vision from Narnia, but can be found right here on planet Earth - in the Arctic Ocean, to be exact. The flowers are formed from frozen atmospheric moisture and, as well as being beautiful, are providing valuable insights into what goes on in these icy waters.

As seawater begins to freeze, water in the newly-formed ice evaporates into the atmosphere. But the overlying air is too cold to hold much of this extra vapour, so the water turns back into ice, creating these intricate flowers.

"The biggest frost flowers in this picture are around the size of a tennis ball," says Jeff Bowman, an oceanography student at the University of Washington. "Once established, they start to pull up brine from the sea ice, so they can end up five times saltier than the surrounding seawater."

Frost flowers also draw out bacteria from the ice. So Bowman and his colleagues 'pick' the flowers, to study the tiny creatures within and get a better understanding of the processes they're involved with.

PHOTO: MATTHIAS WIETZ



REPLY

Your opinions on science, technology and our magazine



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Letters may be edited for publication

MESSAGE OF THE MONTH



Can we learn from
the mantis shrimp's
sophisticated eyes?

The eyes have it

Surely the boys and girls at Lytro have missed a trick? Reading the review of their camera [p75, February], it seems they have a sensor which can “capture everything – colour, intensity and direction” about the light rays entering the camera. But in your article on the Brian Cox series *Wonders Of Life*, you describe the mantis shrimp’s eyes, which appear to have a similar capability – but with a 360-degree field of view, and with none of the Lytro’s complicated optics.

Given a spherical surface studded with sensors that can detect direction as well as intensity, you should in theory be able to reconstruct any photo that could have

been taken within the volume of the sphere from the information captured. You could also reconstruct some images that could have been taken in front of, or behind, the sphere by selecting only rays that would have converged at these points. Given two of these spheres (as in the mantis shrimp), you could even do this in 3D! As to the claim that the mathematics involved would have “once required the use of a supercomputer,” surely the tiny mantis shrimp’s brain is performing this task in real time?

Perhaps Lytro are looking at the problem from the wrong angle?

Shaun Lowry, Hamble

Packing them in

In your Q&A answer on p83 of the February issue, regarding the area the world’s population would cover, you state that three times the world’s population could fit on the Isle of Wight and that, even with all three ferries running round the clock, it would take 432 years to get them all on. But wouldn’t the world’s population be increasing faster on the mainland than the ferries could get them across? If so, the queue for the ferries would never end and we’d never get everyone onto the island. Not to mention Hampshire having to become an enormous graveyard as millions would die waiting in the queue!

Rob Stewart, Keynsham, Somerset

I just read your answer to “if everyone stood together”, and you state that the world population could all stand on the Isle of Wight three times over. Well, sorry to say, your answer is wrong. The Isle of Wight is only 381km², so although 1,000km² would house all of us nicely, I don’t think the tide goes out that far! However, in 1945 we would have all fitted in, with a beachfront view for some. Great magazine, and keep up the good work.

Andrew Rayner

Andrew is correct. Today, we’d need the Isle of Wight, Isle of Man and Jersey to cope with everyone on Earth. –Ed

Unable to count

In the February edition of *Focus*, you state: “The Piraha tribe who live in the Amazon rainforest have no words for numbers, which means they are unable to count” (Q&A, p86). What a ridiculous statement! Who believes you need a word before you can form a concept? If I caught two fish for the table yesterday but three today, I know I have more to eat today. I may not be able to communicate my fortune to my neighbour eloquently but I know the difference, hence I can count. A concept comes before a word – not the other way around.

Andrew Maxey

The Piraha tribe have words for the concepts of large amounts and small amounts, but counting is said to require

**Write
in and
win!**



The writer of next issue’s Message of the Month will win Kaspersky Internet Security 2013 worth £49.99. It’s designed to protect your Windows PC from cyber criminals and malware attacks and gives you extra security for online shopping as well as parental controls.

words representing individual numbers. Various researchers claim that they are unable to count – although one says they can, but choose not to. –Ed

False projections

I was surprised, if not a little shocked, at your use of the traditional Mercator world map to show the locations visited by Brian Cox during the making of the new *Wonders Of Life* series (p37, February 2013). I grew up thinking that Greenland was much larger than China (it is four times smaller) and that North America is considerably bigger than Africa, which is actually 50 per cent larger. The truth hit home when I inadvertently discovered the Peters Projection map, which shows countries in proportion to their area.

Isn't it time we raised the next generation of enquiring minds to have a balanced view of the world? Educational magazines such as *Focus* have a key role to play in this ambition.

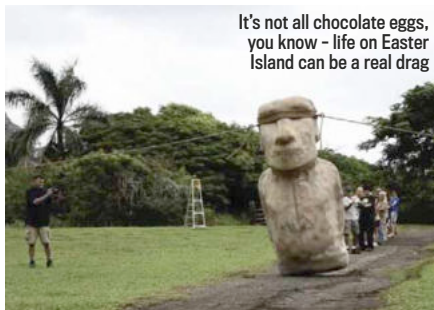
Matthew Sreeves, East Yorkshire

Easter island rocks

On p24 of the January issue, Dr Carl Lipo says he has 'proved' the giant stone statues of Easter Island 'walked' out of their quarries by making a four-tonne replica 'walk' in Hawaii, rocking it back and forth with ropes. By what leap of imagination does this prove that Easter Islanders used a similar technique to make their 74-tonne behemoths 'walk'? By the same token, he has now presumably 'proved' how the Ancient Britons moved their megaliths to Stonehenge and how the Ancient Egyptians moved their blocks of stone from the Nile barges to Giza.

Just why do some so-called 'learned' people persist in ignoring the feats of Thor Heyerdahl on Easter Island? More than half a century ago, the man actually moved a moai three times the weight of Lipo's over half a kilometre; raised and mounted another one onto an ahu platform and then crowned it with the red top-knot. How did he do all this? By getting the islanders to demonstrate how their ancestors had done it. Now what a good idea that was, instead of theorising on an island over 1,000 miles distant.

Bob Burr



Ready for take-off

There was an interesting article in February's Q&A (p83) explaining that spacecraft take off west to east to get assistance from the Earth's rotation, and that planes travelling west to east have shorter flight times. Presumably, the aircraft also weighs less and uses less fuel travelling in that direction. Come to think of it, we are all fractionally heavier than the scales say unless we weigh ourselves when running at Earth's rotational velocity in an east to west direction.

The critical part of the ISS's orbital velocity has to be in relation to the centre of mass of the Earth-Moon system at any time. I assume the mass centre of the Solar System, our Galaxy and the rest of the Universe all play a part. Those people in the ISS must be thankful that it is only a small part, or they could end halfway across the Universe!

Terry Holland



YOUR COMMENTS ON TWITTER

On twitter.com/sciencefocus, we asked:

Which archaeological finds could top the discovery and identification of King Richard III?

@Geese1968 For me, it would be the unearthing of Harold II's remains. Not much chance of that, as apparently he was chopped to bits.

@AI83white I would go for finding Jesus or Adam. That would do it.

Jim @NexusJim Actual proof that aliens did give the Ancient Egyptians a helping hand!

@ChrisMelv Discovering Genghis Khan's tomb would top that easily!

Carry on the conversation using the hashtag #futurearchaeology

FOCUS

SCIENCE AND TECHNOLOGY

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THE FUTURE OF HI-FI

Have your entire music collection at your fingertips with a high-quality end-to-end streaming system from Naim



The digital music revolution has made listening to your favourite music more convenient than ever. A

streaming music system makes your entire music collection available at the touch of a button – and thanks to the Naim range of streaming products, the convenience of streaming music doesn't come at the cost of audio quality. Even better, unlike some of its competitors, Naim can look after your needs at every stage of the streaming journey, from storing your tunes to playing them. Read on to get started on your streaming journey.



Getting connected

The world of streaming audio relies on using an internet connection. Naim recommends a Netgear router or Apple's Airport Express for the best performance. For a wired connection, use a Cat5 network Ethernet cable or add a wireless switch to your router for complete flexibility.



RIP ▼

CATALOGUE ▼

STORE ▼

▼ HDX hard disk player / server



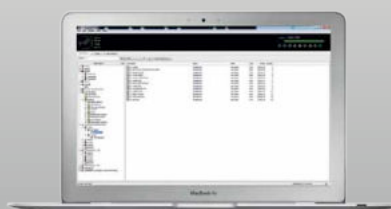
Rediscover your existing collection

The convenience of having your entire CD collection available at the touch of a button is one of the key advantages of a streaming system. Your existing collection, as well as CDs you buy in the future, can easily be made available to stream by 'ripping' them to make digital copies.

For maximum simplicity, you can choose a Naim device that can rip and store your CDs. The HDX and UnitiServe can both make bit-perfect copies of your music using Naim's custom-designed ripping engine, storing music either to their internal 2TB hard drives or to a network-attached storage (NAS) drive.

Keep your collection organised

Having thousands of songs at your disposal requires organisation, and Naim's custom-designed Extended Music Database takes care of that for you. The Naim HDX or UnitiServe will categorise every track they rip by name, artist, composer and a host of other searchable criteria, and will even find album artwork to display. You can install Naim's Desktop Client on your computer to search, edit and manage stored music over your home network.



▲ Manage your music using Naim's Desktop Client application

▼ UnitiServe hard disk player / server



Where to keep your music

For those short on space, the Naim HDX and UnitiServe will store as well as rip your music, with 2TB of space allowing you to store up to 2400 albums in hi-resolution uncompressed audio.

Prefer to keep your music on a NAS drive? Naim's HDX and UnitiServe hard disk players are also available in solid state variants, which purely rip straight to NAS. And if you wish to listen to your music elsewhere in the home, Naim's streaming players will stream direct from your music store, whether it's a Naim server or a NAS drive.



UPGRADE

Take your streaming up a notch

There's always room for improvement and your streaming journey doesn't need to end once you've got your system sorted. The best can always get better and that's exactly what's possible with Naim's simple upgrade path.

For over 25 years Naim has offered users their system with the addition of an external power supply and, more recently, the option of an external DAC, adding more performance while also boosting sound quality.

Now, upgraders will get an even better deal as upgradeable power supplies include Naim's new revolutionary discrete regulator, ensuring you get the best sound quality possible.

BACK UP ▼

Peace of mind

It's always important to keep your music library backed up, and luckily Naim makes this potentially difficult and lengthy process easy and pain-free.

Naim hard disk players like the UnitiServe and HDX offer the option to back up your tracks automatically, by creating duplicate versions of your ripped tracks and storing them on an allocated storage device, such as a connected NAS drive. This can also be used as overflow storage for audiophiles who fill up the HDX and UnitiServe's built-in 2TB hard drive, with the content streamable by any of Naim's network music players or all-in-ones.



CONTROL ▼



◀ n-Stream control app

Complete control however you choose

Naim's free remote apps for iOS devices put the ability to browse and play your music in the palm of your hand.

The Naim n-Stream app works with Naim's range of network players and all-in-one systems, allowing you to flick through album artwork, select music and build playlists. Alternatively, if you have a Naim hard disk player/server, the free n-Serve app will put you in charge of all your stored tunes.

PLAY ▼

Convenience and quality

Whether you prefer the audiophile performance of separates or the convenience of an all-in-one system, Naim has a streaming solution for you. Choose from Naim's NDS, NDX, or ND5 XS network players with matching Naim amplification or the new NAC-N 172 XS streaming preamplifier. Alternatively a SuperUniti, new NaimUniti 2, new UnitiLite or UnitiQute will provide all-in-one convenience alongside Naim quality sound. They all support a range of file formats too, including hi-res audio up to 32bit/192kHz.

▼ UnitiQute all-in-one system



▲ The NEW UnitiLite all-in-one system

Dell recommends Windows.

This is the story of
Thomas and the alternate universe.

From 9 to 5, Thomas was all business.
But as he boarded the train, he entered a different world.
With his laptop, he created a graphic novel where
anything was possible.

Twice a day, Thomas took the train
far beyond the imaginable.



With a simple flip, the Dell™ XPS™ 12 Ultrabook™, converts from laptop to tablet. Responsive touchscreen, full HD display and Intel® Core™ i7 processor let you follow inspiration wherever it takes you. Powered by Windows 8. Learn more at Dell.co.uk/xps12



The power to do more

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DISCOVERIES

News and views from the world of science

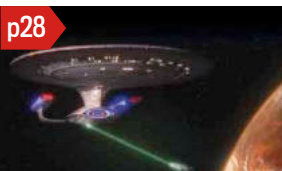
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INSECT DRIVES ROBOT CAR

Why scientists
are letting moths
control four-
wheeled robots

p28



TRACTOR BEAM TESTED

Scientists have made
one, but instead of
starships it's tugging
microscopic particles

p31



YOUR NOSE IS QUANTUM

New evidence
suggests that
smell uses
quantum effects

THE BIG STORY

DNA tests prove bones belong to Richard III

Scientists confirm that a twisted skeleton found under a car park belongs to the legendary royal

SINCE ANNOUNCING THE discovery of Richard III's remains under a car park, researchers have been inundated with emails from people claiming to be related to England's most vilified king.

The skeleton, believed to be that of the medieval monarch, was found in Leicester city centre. Amidst the radiocarbon dating, forensic analysis and osteological (bone) studies, it is the genetic techniques used to test the skeleton's relatedness to modern day descendants of Richard III that have garnered the most interest.

Turi King, a geneticist at the University of Leicester, explains that to test the skeleton's identity she extracted DNA from the remains, sequenced it and compared the sequences she obtained with those of two living relatives of the historical monarch.

A key obstacle to the testing of old genetic samples is that DNA becomes damaged over time. To get around this problem, King did not look at the nuclear DNA from the skeleton's chromosomes, and instead focused on the DNA contained within mitochondria, the sub-cellular



The skull of King Richard III bears marks from multiple wounds sustained on the battlefield



PHOTO: UNIVERSITY OF LEICESTER



Was Richard III really a hunchback? The twisted spine of his skeleton reveals that Shakespeare's famous depiction is accurate



compartments that work like engines to provide each cell's energy.

"After death, our DNA degrades," explains King. "As we just have one copy of our nuclear DNA in each of our cells, but many hundreds to thousands of copies of mitochondrial DNA, then mitochondrial DNA is the easiest DNA to retrieve from ancient remains."

Once she had managed to extract DNA from the skeleton, King used a combination of conventional sequencing techniques and newer, 'next generation' methods to read the mitochondrial DNA's genetic code. King then compared these sequences with those taken from Richard III's two living

descendants, and found a match between all three sets of genetic code, also known as haplotypes.

The researchers say that the code sequence shared by the skeleton and the two descendants is rare enough to suggest that they are indeed related, although this is based on the assumption that different mitochondrial haplotypes were roughly as common in the general population at the time of Richard III as they are today.

"It is a relatively rare type," says King. "This strengthened the DNA case further but, as I've always stressed, DNA has to be taken alongside archaeological and osteological (bone) evidence. Like a forensic case, you wouldn't just take the DNA evidence on its own."

For now, however, we have to take the researchers' word for it, as the team are some months away from publishing the details of the specific DNA sequences they examined, and the methods they used to compare them. "I'm able to give the punchline," says King, "but the details of how I got there will have to wait for the academic publication."

KELLY OAKES



Dr Turi King collects a DNA sample from Michael Ibsen, a descendant of Richard III



TIMELINE

A history of ancient DNA investigations

1989

Scientists use a technique called polymerase chain reaction to amplify mitochondrial DNA from bones that are between 300 and 5,500 years old.

1994

Comparison of chromosomal and mitochondrial DNA with living relatives confirms that five skeletons discovered in Russia are those of Tsar Nicholas II, Tsarina Alexandra, and three of their children.



2010

Researchers use polymerase chain reaction to compare the length of chromosomal DNA sequences between Tutankhamun and some of his mummified relatives.



2010

Next-generation sequencing methods, better suited to the short fragments of DNA found in ancient specimens, are used to compile a draft Neanderthal genome sequence from the bones of three individuals.

ANALYSIS

Professor Thomas Gilbert



Centre for GeoGenetics, University of Copenhagen



THE DNA ANALYSIS here seems to have been carried out using fairly

standard methods that have been used in the ancient DNA field for a good 20 years. Mitochondrial DNA is the easiest to work with, so it's the marker of choice. Using mitochondrial DNA is not as conclusive as comparing differences in nuclear chromosomal DNA, but if the nuclear DNA is too degraded, then using mitochondrial DNA is the only option.

As for the reliability of the findings, it really comes down to how unique the mitochondrial DNA haplotype is, and therefore the chance of getting a match with 'unrelated' individuals. You can calculate the probability of the match between DNA sequences based on the frequency of the haplotype today. Obviously you can't be 100 per cent certain, but in combination with the other evidence it's at least very likely.

What is key to remember is that on its own, the DNA is not conclusive evidence, so it's important to have the supporting information. To be more certain, the team could try analysing nuclear DNA from the skeleton and comparing it with some closer relatives. If any of Richard III's brothers, sisters or father are buried anywhere, then these would be the obvious choice.



WHAT DO YOU THINK?

Let us know your thoughts at facebook.com/sciencefocus



Georgia Tech student Natasha DeLeon-Rodriguez holds a sample of high-altitude bacteria

Biology

Microbes found 10km up

BACTERIA, IT SEEMS, can get everywhere: even hostile environments such as Antarctic lakes and deep-sea volcanic vents are home to the tiny creatures. Now, scientists in the US have found microbes high up in the atmosphere, a discovery that suggests bacteria could play a more significant role in our weather than was previously thought.

In 2010, NASA sent out a fleet of aircraft to study the atmosphere before, during, and after hurricanes over the Caribbean and the Gulf of Mexico. This provided researchers with the perfect opportunity to collect air samples from the troposphere, the portion of the atmosphere around 8-10km (5-6 miles) above the Earth's surface. Analysing the samples back in the lab, the researchers found a veritable zoo of bacteria – 314 types in total.

"We weren't expecting to find so many bacteria," says Prof Athanasios Nenes at the Georgia Institute of Technology. "What was even more surprising was that more than 60 per cent of them were alive. This environment poses big challenges for life – freezing

temperatures, scarce food and high UV radiation – but these bacteria manage to survive."

The researchers aren't yet sure whether bacteria actually live and reproduce in the atmosphere, or whether they're just being whisked up by the winds – especially since air masses over oceans were found to host mostly marine bacteria, while terrestrial bacteria were found predominantly in air masses over land. Nevertheless, these sky-high microbes are of great interest to climate scientists because they could act as nuclei around which icy clouds form.

"Based on the sheer number of bacteria we've seen, they may be having an impact on the clouds up there, which could in turn affect the Earth's energy balance that drives weather and climate," says Nenes. "There are climate modellers who are now interested in including a biological particle cycle in their models. This would give us a better idea of whether these microbes really can alter the climate."

JAMES LLOYD

1 MINUTE EXPERT

Cubic boron nitride

What is it?

A compound, made of boron and nitrogen, that is not found in nature but can be made in the lab. The conventional form of the material is very hard, though not as hard as diamond.

Why is it in the news?

Because scientists in the US and China were able to make it even harder than diamond. By applying high temperatures and pressures to pellets made from round nanoparticles of boron nitride, the team were able to shrink structures within the particles. This made the boron nitride incredibly tough.

What can it be used for?

It has a wide range of industrial uses from cutting through tough materials to drilling. And because of its high chemical stability and its ability to withstand extreme temperatures, it can be used in applications such as machining steel, where diamond would be unsuitable.

What's next?

The samples were just a couple of millimetres across. The plan is to create larger samples that can be tested in cutting tools. But the method could also be applied to diamond, which could lead to even harder materials.

WHO'S IN THE NEWS?

David Gump

Chief Executive of Deep Space Industries

What did he say?

Gump announced that his company is joining the race to harvest rare metals from nearby asteroids. "More than 900 new asteroids that pass near Earth are discovered every year," he said. "They can be like the Iron Range of Minnesota was for the Detroit car industry last century

– a key resource located close to where it was needed."

When will the space mining begin?

Deep Space Industries plans to send out a fleet of spacecraft, dubbed FireFlies, in 2015 to scout for suitable asteroids. A year later, larger spacecraft called DragonFlies will embark

on round trips to capture and bring back samples.

What was the reaction?

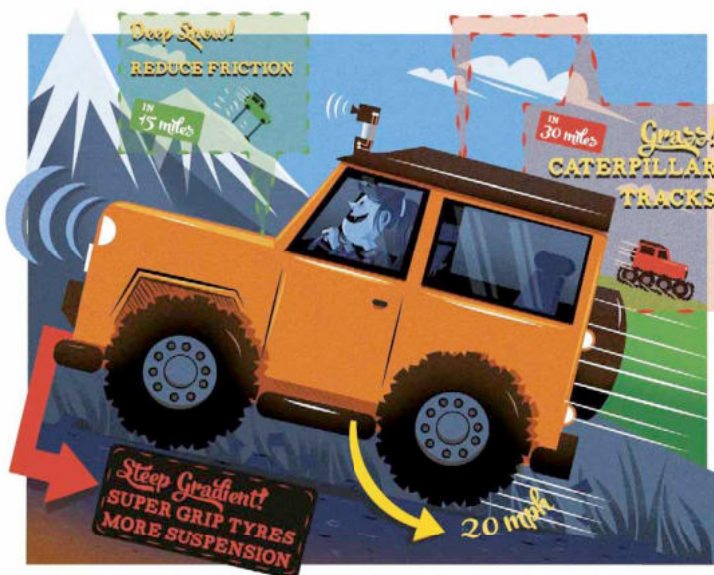
Despite Gump's confidence, many experts are sceptical about the project's economic feasibility, pointing out that a forthcoming NASA mission to collect no more than 2kg of asteroid material will cost a whopping \$1 billion.





PATENTLY OBVIOUS

Inventions and discoveries that will change the world with James Lloyd



Futuristic four-by-fours

LAND ROVERS ARE known for their ability to traverse tricky terrain, and soon they could have a computerised brain that will help the driver negotiate tough surfaces. The British car manufacturer is looking to develop a system that automatically detects the type of surface that the vehicle is about to encounter.

It could do this by analysing an image of the upcoming terrain and picking out any telltale colour and texture details. The system would then check the

result by comparing the car's GPS location to a geographical database of terrain type. Once the surface is detected, the Land Rover would adjust its steering, brakes, and suspension settings accordingly.

In grass, gravel or snow, for instance, the vehicle might switch to a low-friction mode, reducing the driver's chances of skidding off into a ditch. It might even be useful on the school run!

Patent application number:
UK 2492953

Google's vibrating glasses

CURRENTLY IN DEVELOPMENT, Google's Project Glass are augmented reality specs that will provide you with a stream of information through a transparent lens – whether that be maps, messages or a train timetable.

Now Google has revealed how Project Glass wearers will also be able to listen to audio. But since headphones tend to be rather bulky, the company plans to pass sound waves directly to your ears by means of 'bone conduction'.

Already employed in some headphones and hearing aids, bone conduction sends audio vibrations through your skull and into the bones of the inner ear. In Project Glass, these vibrations will be created by an electromechanical transducer that converts electrical signals into mechanical ones. When this vibrates it shakes the glasses, which then pass the vibration on to the skull.

Patent application number:
US 20130022220



Draw a world in 3D

DISNEY THEME PARKS might soon let you star in your own 3D animation. Disney's 3D drawing system employs tracking devices to follow a wand that you hold. As you move the wand, an object is sketched on a screen that can be viewed with 3D glasses. The system captures you in three dimensions and then beams you into an action scene. As you run from a rolling boulder, for instance, you could use the wand to draw a bridge over a ravine.

Patent application number:
US 20130002815

Silkmoths are on the ball when it comes to robots



THEY DID WHAT?!

Silkmoths given robots to drive

What did they do?
Scientists at the University of Tokyo have built a two-wheeled robot that can be driven by a moth.

How did they do this?

The silkmoth controls the robot by walking on a polystyrene ball that's mounted in the centre of the device. Rotating this ball steers the robot, rather like a computer trackball controlling a cursor. In order to simulate the airflow that the insect would feel while flying, the robot was placed in a wind tunnel.

Why did they do it?

The researchers used the small robot to study how the silkmoth tracks down pheromones – chemicals that can signal a nearby mate. Understanding the insects' tracking skills might be able to help scientists develop robots that can detect odours from environmental spills and leaks.



BEAT AN ITCHY SCALP†



Joe Hart,
England Goalkeeper



Get instant relief with head & shoulders Itchy Scalp Care shampoo¹, a new formula with extract of eucalyptus. Now also available in new Itchy Scalp Care 2in1.

*Visible flakes seen at 2ft with regular use. †Itch associated with dandruff.



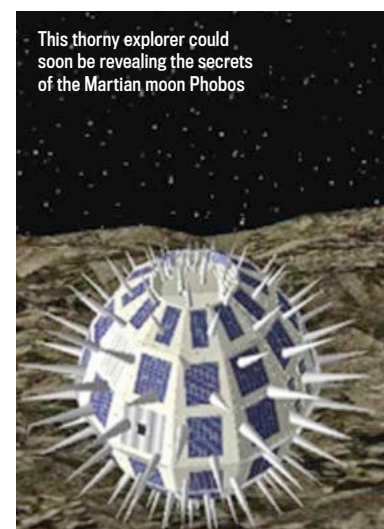
Space exploration

'Hedgehog' rovers to invade Martian moon

WATCH OUT CURIOSITY – a new breed of rover may soon be snapping at your wheels. Researchers in the US have designed a spiky, beach ball-sized robot that could be bounding across the Martian moon Phobos within 10 years. Unlike today's rovers, these 'hedgehogs' don't sport wheels. Instead, three rotating discs within enable them to move around. Spinning the discs enables the rover to hop, with the spikes providing grip.

The aim of the rovers is to find out more about the mysterious moon. "We don't currently know whether Phobos is a captured asteroid or a piece of Mars that was ejected by an impact," says Prof Marco Pavone at Stanford University.

JAMES LLOYD



This thorny explorer could soon be revealing the secrets of the Martian moon Phobos

Genetics

Found in humans: four-sided DNA

Fluorescent markers reveal the presence of the four-sided DNA as pink blobs in cells

AFTER MORE THAN 100 years of looking, scientists have finally tracked down a strange, four-stranded form of DNA. Our genetic code is usually incorporated in two strands of genetic material that wrap around one another, forming the famous 'double helix' structure. The discovery shows some of our genes are actually incorporated in a 'quadruple helix'.

These quadruplexes have been spotted in microorganisms before, but it's the first time they've been seen in humans. It's thought they may be involved in the development of some cancers, providing new avenues of research into treatments.

Professor Shankar Balasubramanian at the University of Cambridge, lead author of the study published in the journal *Nature Chemistry*, describes the quadruplexes as 'exotic knots'. Regions of DNA rich in

the compound guanine, one of the four chemicals that makes up the genetic code, are particularly prone to forming the four-stranded DNA.

Balasubramanian and his team conducted a computerised survey to search for guanine-rich sequences. They found them all over the human genome.

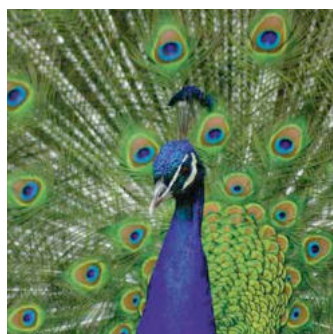
Research is already under way into how to use synthetic molecules to trap and contain quadruplexes – stopping cells dividing and therefore preventing cancer. "The research indicates that quadruplexes are more likely to occur in genes of cells that are rapidly dividing, such as cancer cells," says Balasubramanian. "For us, it strongly supports the idea of investigating the use of these four-stranded structures as targets for personalised treatments."

ZOE CORMIER

NEWS IN BRIEF

Peacock power

➤ The iridescent feathers of the peacock are the inspiration for new research into colour E-ink displays. The feathers have tiny grooves that reflect different wavelengths of light. Now, researchers at the University of Michigan have used nanoscale grooves of differing widths to create a surface that traps some colours and reflects others, creating a bright, full-colour image.



We have peacocks to thank for better displays

Boom and burst

➤ Supernovae and solar flares were among the suspects, but it seems another cosmic event was behind a blast of high-energy radiation that hit Earth in the 8th Century. Scientists at the University of Jena, Germany, have figured out that the blast was a short gamma-ray burst, a powerful explosion of energy thought to be caused by the merger of two neutron stars.

Unforgettable updates

➤ We remember Facebook posts better than we remember faces. So says research by psychologist Laura Mickes of Warwick University. But what about posts versus other sorts of writing – book sentences, say? Well, the posts have it again. It seems the chatty nature of the information in a post is in a 'mind-ready' format, making it easier for our brains to remember.

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Environmental science

Clean coal technology comes a step closer



C OAL MAY HAVE a place in a low-emission future after all, new research at Ohio State University suggests. Using a technique called Coal-Direct Chemical Looping (CDCL), a team led by Prof Liang-Shih Fan claims to be able to release energy from coal while capturing 99 per cent of the CO₂ emitted.

CDCL works by extracting coal's energy via a chemical reaction, rather than by combustion. A mixture of powdered coal and 2mm beads of iron oxide is heated inside a 7.6m (25ft) metal cylinder. Carbon in the coal and oxygen from the beads

react to form CO₂ which can be captured for recycling or stored in a reservoir. Crucially, this reaction gives off thermal energy that could be used to heat water in order to drive electricity-producing steam turbines. The other waste products are iron beads that can be reoxidised and reused, and coal ash.

So far the team has achieved 203 hours of continuous energy production on a small scale, and a larger-scale pilot plant is now being built at the US National Carbon Capture Center in Alabama.

RUSSELL DEEKS



Physics

Star Trek-style tractor beam is developed

SCIENCE FICTION SPACECRAFT have long been using them to grab other ships and grapple cargo, and now scientists have created a real-life tractor beam. But its first uses are unlikely to be in space.

The tractor beam is actually a laser that attracts microscopic particles – no mean feat given that the light particles within a laser, the photons, usually push an object along the direction of the beam. But researchers at the Institute of Scientific Instruments in the Czech Republic and the University of St Andrews in Scotland say they have found a way to reverse this 'radiation pressure'.

The strength of the beam determines the size of the particles that it attracts, but the process also involves some transfer of energy to the object being moved. This means that the beam is most likely to be first used in a medical laboratory to separate out white blood cells, rather than for rescuing spacecraft in distress, because it would result in the ship becoming overheated. **JAMES LLOYD**

Personal security

Visor protects your anonymity

DOES THE RISE of drones, security cameras and facial recognition software give you nightmares? Don't worry – help is at hand in the form of this 'privacy visor'. Japanese inventors at the National Institute of Informatics have devised a pair of glasses fringed with near-infrared purple lights. The lights flummox facial recognition software by creating 'noise' in the image. Several

companies have already expressed interest in producing the glasses.

The growing ubiquity of image recognition software is prompting a rash of research into thwarting it. For example, US designer Adam Harvey has been working on face paint and clothing that acts as camouflage to computer vision: for more see <http://cvdazzle.com>

ZOE CORMIER



So you want to look inconspicuous? Why not try these low-profile specs?

Scream if you want to go



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DIGITAL WORLD

Science on the web

SOLAR SYSTEM

<http://visual.ly/solar-system-0?view=true>

Ever have trouble imagining just how big the Sun really is? Or how closely packed all of the rocky planets are? This Solar System visualisation should help. Switch to 'Size', 'Speed' or 'Distance' to change your perspective – but be aware that even this model is not *exactly* to scale.



Get a sense of your place in the Solar System

OUCH

www.sciencemuseum.org.uk/onlinestuff/games/painless.aspx

This is not the best game to play when you have a headache. But *Ouch*, brought to you by the Science Museum, could certainly help you think about the best way to treat one. Use painkillers, placebo pills, and even spider venom – a possible future pain treatment – to destroy bolts of pain.

EVERY LAST DROP

<http://everylastdrop.co.uk>

This is the United Nations International Year of Water Cooperation, with 22 March being World Water Day. This website takes you from the 40 litres of water used for a five-minute shower to the surprising 130 litres that go into making a cup of coffee.

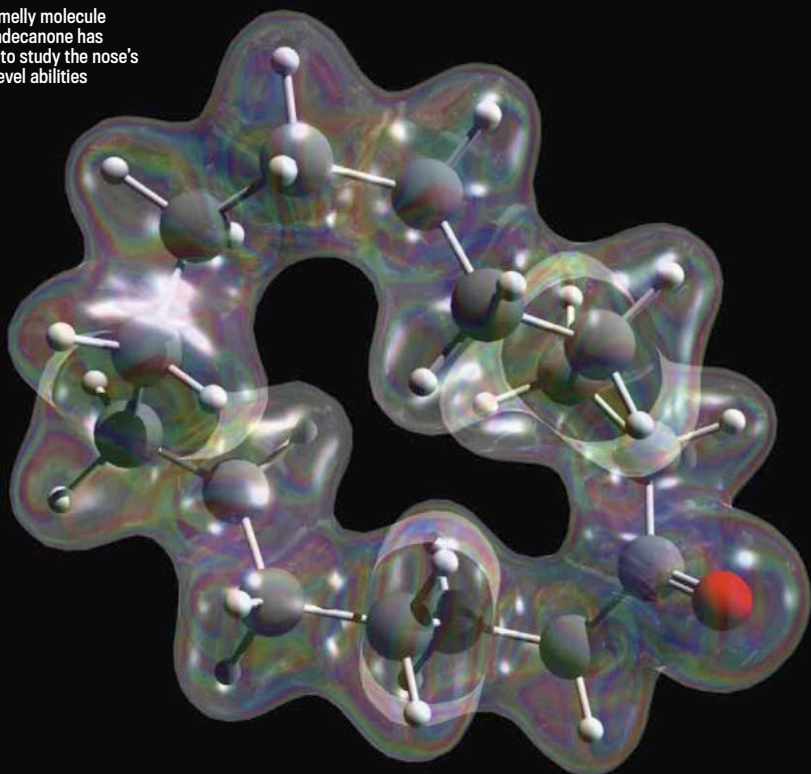
WALLACE LETTERS ONLINE

www.nhm.ac.uk/wallacelettersonline

Over 4,000 of the letters written or received by naturalist Alfred Russel Wallace are now online in this searchable database from the Natural History Museum. Gems include letters between Wallace and Charles Darwin, with whom he discovered evolution by natural selection.

KELLY OAKES

The very smelly molecule cyclopentadecanone has been used to study the nose's quantum-level abilities



Quantum biology

The sense of smell stinks of quantum effects

STRANGE QUANTUM PHENOMENA are responsible for our sense of smell, new research shows. The conventional wisdom is that it's a molecule's specific shape that allows our noses to distinguish between one smell and another. But there's new evidence that it's actually the frequency of a molecule's vibration, a quantum effect, that's all-important.

Most olfactory (smell) scientists believe that receptors within our noses act like a lock that can only be activated by a molecule of a specific shape – the 'key'. The trouble is, some molecules with different shapes have similar smells.

Olfactory scientist Dr Luca Turin of the Alexander Fleming Biomedical Sciences Research Center in Greece, has set about gathering evidence of quantum

phenomena up our nostrils. He created a smelly molecule, cyclopentadecanone, specifically for the job. The molecule comes in two forms – both are the same shape but vibrate at a different frequency, having differing proportions of hydrogen and its heavier cousin deuterium in them. He found that the volunteers were able to distinguish the two versions.

Molecules are collections of atoms that can be thought of as being connected by springs that can vibrate. It's the detection of these vibrations that Turin says is responsible for our sense of smell. If the vibration is at the right frequency for a receptor, it triggers a 'quantum tunneling effect', an electron travelling across the receptor and triggering it. But Turin faces an uphill battle to get his theory to take hold – other olfactory scientists have been decidedly sniffy about the idea.

So will this new evidence change things? "I don't think so," says Turin. "I take the Max Planck point of view – people don't change their mind, they just die."

ZOE CORMIER



GRAPHIC SCIENCE

Seeing research differently

HEATING THE WORLD

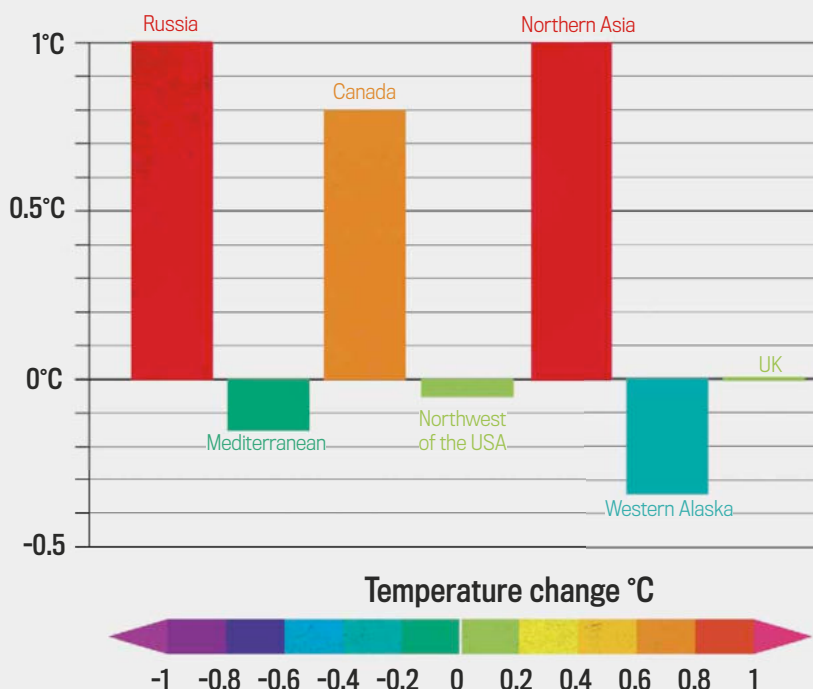
OUR CARS, HEATERS and air-con units (pictured inset) are causing temperatures to change in cities hundreds of kilometres away. US scientists have worked out the knock-on effects of technology that takes in energy and throws out waste heat. They ran a climate model twice – once including figures for waste heat produced by technology and another without this extra heat, to see its effect over a period from December to February. It is thought our waste heat causes its climate-changing effects by shifting jet streams, so some areas are cooled while others heat up.



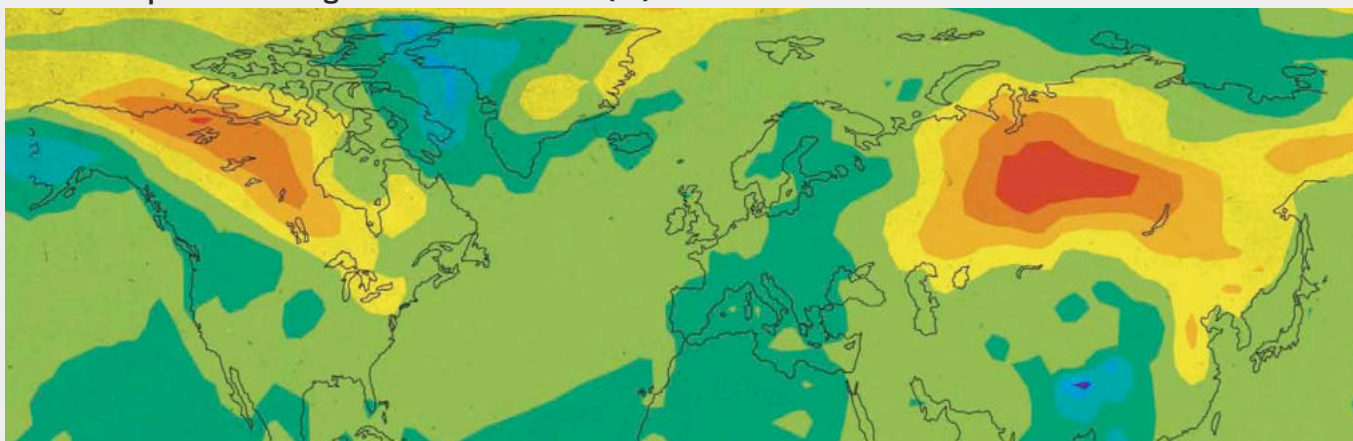
“Energy use from multiple urban areas can collectively warm the atmosphere thousands of miles away from where the energy was consumed.”

Guang Zhang, University of California, San Diego

Biggest winter (December–February) temperature changes



Winter temperature changes due to waste heat (°C)



NEWS IN BRIEF

Underwater world

• Ancient life has been found in Antarctica's ice-covered Lake Whillans – and the US team behind the discovery are now analysing its DNA to find out exactly what it is. The organisms found are thought to be chemolithotrophs, which use iron and sulphur for nourishment, but are now being tested to ensure they were not introduced by the drilling process.

A US team member on-site in Antarctica where ancient life has been found



Leadership in your genes

• If you're lucky enough to be blessed with a specific gene, you're more likely to be a natural leader. Scientists at University College London analysed 4,000 people's DNA and found that if they have the gene rs4950, they were 25 per cent more likely to be in a supervisory role at work. Employers could one day run tests on applicants to see if they have leadership potential.

Salmon have Mag-Nav

• To spawn, salmon navigate across the ocean back to the rivers where they hatched using Earth's magnetic field. A study used 56 years of data showing the routes taken by the fish. Earth's magnetic field shifts over time, and the fish were found to follow the path that had a magnetic field most similar to that of the river when they left.

Continue the epic story of StarCraft II where Wings Of Liberty left off.

STAR CRAFT II

HEART OF THE SWARM

Heart Of The Swarm, due for launch on the **12 March**, will take you to uncharted worlds, delving deeper into the hive mind of the insectoid Zerg and is set to be the most explosive and exciting competitive gaming experience of 2013!

Battle as Kerrigan, the former Queen of Blades, as she tries to restore her strength and regain control of the Swarm over 20 new campaign missions, featuring new gameplay mechanics allowing evolution of abilities and units for the Zerg army.



As with Wings Of Liberty the battlefield doesn't end there. There are new multiplayer units and maps, as well as expanded features and functionality on Battle.net. Play as the humanoid Terran, the ravenous Zerg or the psionic Protoss to climb the ladder and become victorious over your opponents.

With the game's imminent arrival players are also being invited to attend official events in Melbourne, Seoul, Versailles and Irvine. The top pro-gamers will be fighting in a series of show matches, as well as live demonstrations of new features, videos and content. Don't worry if you aren't able to attend physically; you can catch the celebrations online via the Blizzard website.

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- Heart Of The Swarm Collector's Edition
- Wings Of Liberty Standard Edition



To be in with a chance go to www.sciencefocus.com/competitions today!



A health official culls ducks infected with bird flu in Indonesia in February this year

HOT TOPIC

Should we be developing a more contagious bird flu?

→ AFTER A ONE-YEAR break, scientists are set to resume controversial research to create a more contagious strain of bird flu.

The bird flu virus – known as H5N1 – has so far infected around 600 people worldwide, mostly through contact with diseased birds. Of those, 359 have died. However, researchers at the Erasmus University Rotterdam in the Netherlands and the University of Wisconsin-Madison in the US found that it would take

only five to nine mutations in the virus's DNA to allow it to pass between humans.

When the results came to light, safety fears forced the scientists to suspend their work. They will now study how mutations can make the virus more contagious. They argue that the research will help prevent a catastrophic pandemic, but others worry that the modified virus could escape from the lab or fall into the hands of terrorists.

WHAT DO YOU THINK?

Let us know your opinions at twitter.com/sciencefocus using the hashtag #hottopic, and facebook.com/sciencefocus

Your Tweets and Facebook posts



Alan Murphy: Nature will transmute and adapt by herself, so why would you give her a step-up until we naturally gain some defence against what is out there?



Catriona Hamilton: The only way we can learn the behaviour of bacteria and viruses is to conduct strictly controlled research.



Paul Knight: You play around with fire and you are likely to get burnt.

WHAT THE PAPERS SAY

HENRY GEE

The latest from leading science journals



Living fast needn't mean dying young

WHY DO WE grow old and die? Why does your hamster barely make it to two years, when you might live to be 100?

The popular explanation is that smaller creatures tend to have faster metabolisms and expend lots of energy. But metabolism produces highly damaging waste products, including 'reactive oxygen species' (ROS). These are oxygen atoms and molecules that zip through tissues, ripping holes in cells and blasting DNA. The body can only take so much punishment.

This is the 'live fast, die young' hypothesis. It underpins the health benefits of foods rich in antioxidants, which mop up ROS before they can do too much damage. It sounds like a great idea. The problem is that life isn't as simple as that.

The first cracks in the 'live fast, die young' idea came with the realisation that birds live much longer than mammals of similar mass. Being small, then, clearly isn't necessarily a harbinger of early death. In birds, what seems to be more important is flight. Flight requires an incredible expenditure of energy: if 'live fast, die young' were true,

you'd think that exhausted birds would constantly rain from the sky. And yet many birds migrate huge distances in order to feed and breed. If they can't go the distance, they die. Therefore natural selection could have fixed it that birds have protection against the oxidising products of fast metabolism, allowing them to fly enormous distances.

The same rules apply to the Glanville Fritillary, a butterfly found in Finland. They live in ephemeral patches of meadowland and often have to migrate to find pastures new. Writing in the *Journal Of Experimental Biology*, Kristjan Niitepöld and Ilkka Hanski of the University of Helsinki show that lifespan in these butterflies is related to peak energy expenditure – the harder they fly, the longer they live. Again, it seems that natural selection has fixed it that they can somehow work round the damage caused by fast-running metabolism.

The results echo curious work on a strain of inbred laboratory mouse that's relentlessly active, but lives longer than regular mice. The catch is that it has access to as much food as it likes. This never happens in the wild because food is limited. However, it seems as though natural selection has optimised active creatures to make the best use of the resources they can grab – and to protect them from metabolic damage.

Some people strive to live longer by eating extremely frugally and minding their metabolisms. But if the latest research is borne out, could it be that people can have their cake and eat it, too?

Henry Gee is a palaeontologist and evolutionary biologist, and a senior editor of the journal *Nature*



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INSIDE SCIENCE

ROBERT MATTHEWS

YEARS AGO, AS a Fleet Street reporter, I was mortified to read a front-page exclusive run by a rival daily newspaper, declaring that the missing limbs of the famously armless Venus de Milo had been unearthed in a field. As archaeology was part of my beat as a correspondent, I was expecting what is known in the trade as a major arse-kicking from the news desk for having missed so big a story. So I decided to get it over with and confessed my embarrassment to the news editor – only to have it compounded when he rolled his eyes and said, “What’s today’s date?”.

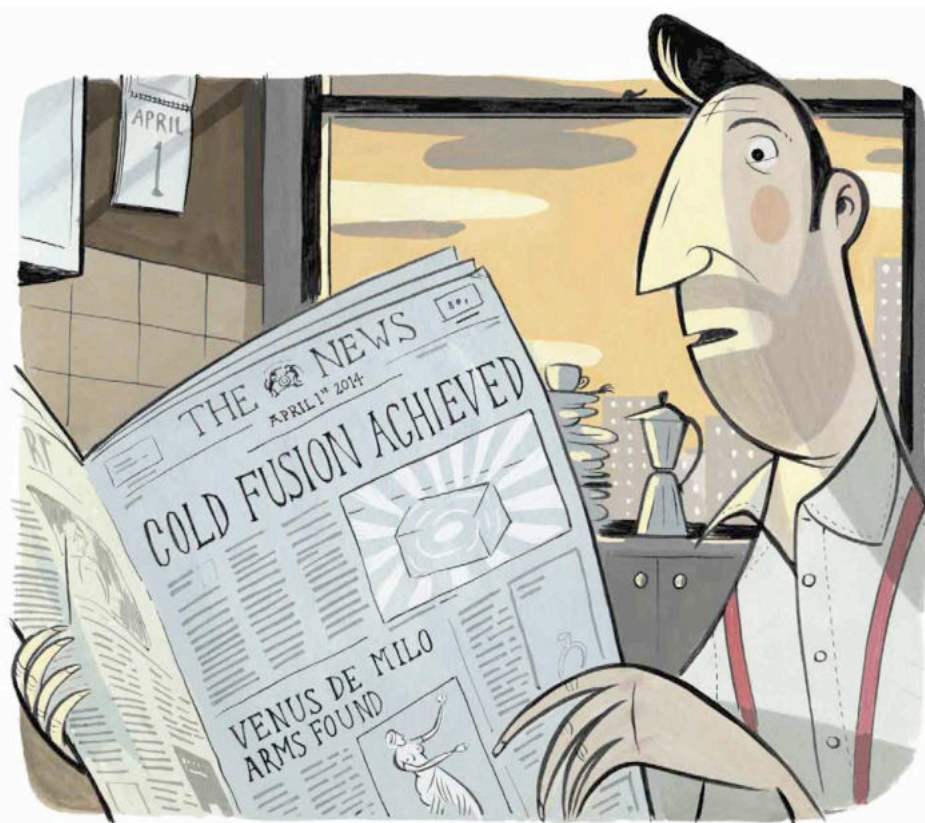
It was, of course, 1 April. I was spared the arse-kicking, but ended up looking a stupid arse instead. It didn’t do my reputation with the news desk much good either – as I discovered a few days later. Leafing through that week’s issue of the journal *Nature*, I came across a paper by a team of Russian scientists reporting research into magnets made of plastic. When I asked the news editor if he wanted a piece about it, though, he said, “Haven’t you had enough of being an April Fool for one year?”

As it happens, the research was genuine. Today, plastic – or more correctly ‘organic polymer’ – magnets are a subject of mainstream research. Yet there seemed little point trying to convince the news editor.

Even 25 years later, I still cringe at the memory of all this. But it did teach me a few lessons about science reporting. First, the sheer outlandishness of some research can make it hard to distinguish breakthroughs from baloney. A story published on April Fool’s day about, say, scientists levitating a frog in a magnetic field would leave many feeling they were having their leg pulled – after all, everyone knows frogs aren’t magnetic. But as Nobel Prize-winning physicist Andre Geim at the University of Manchester and his colleagues showed some years back, frogs – and indeed anything packed with water – possess a property called diamagnetism, which means they repel magnetic force, allowing them to levitate.

My April Fool experience also made me more sympathetic towards scientists who are cagey about commenting on controversial stories. It’s not just that they may look foolish if the story proves to be false – it’s that their reputation could be permanently trashed. This is a particular disaster for scientists, for whom reputation is at least as important as evidence when it comes to convincing their peers.

“If cold fusion really did exist, the researchers making the claim wouldn’t – they’d be killed by the blast”



Small wonder, then, that it’s hard to get scientists to say anything constructive about an issue many readers of this magazine keep asking us to cover: cold fusion, or Low Energy Nuclear Reactions. For anyone that hasn’t come across cold fusion, it’s the idea that nuclear fusion reactions, normally associated with ultra-high temperatures in stars, can be triggered using simple lab equipment.

The original claim, made by a British chemist and his US colleague in 1989, was one of the biggest stories I covered as a Fleet Street reporter. But I remember having that April Fool feeling again when I first heard about it. Phoning scientists, I found most wouldn’t speak on the record, but told me off the record that if cold fusion really did exist, the researchers making the claim wouldn’t – they’d be killed by the resulting blast of neutron radiation. It became clear the experts were weighing up the chances of cold fusion being right, and had decided that, on balance, it was probably baloney.

Almost 25 years on, I think their sceptical view has been justified. If there were something in it, the evidence would be compelling by now. Yes, the lack of such evidence could be the result of some global conspiracy, but on balance, I think that’s baloney too. So I’ve come regretfully to the conclusion that the chances of cold fusion

being vindicated are slimmer than those of the Venus de Milo getting her arms back. But I’d be delighted to be proved wrong, on either count. ■

ROBERT MATTHEWS is Visiting Reader in Science at Aston University, Birmingham



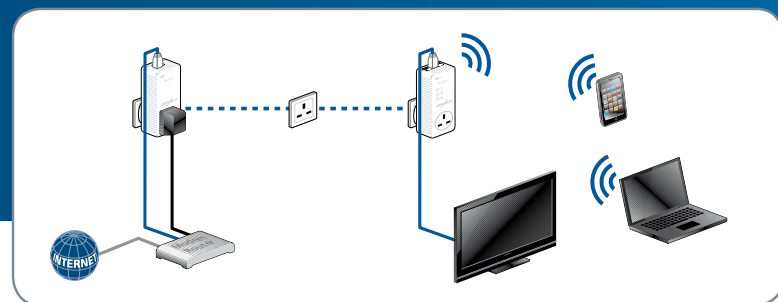
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HIDDEN TREASURES

HELEN CZERSKI

PAPER BAGS ARE great. They crinkle and they rustle and it's nice to transport apples inside a bit of tree. But paper bag perfection is spoiled for me by one thing: a rainy day. The nice, crisp bag soaks up the rain like a sponge, and before you know it the nice, crisp apples are scooting off across the pavement and under the nearest car, where they get smashed into muddy smithereens. It's a sad end for both the paper and the fruit.

But why does that happen? How could something that's perfectly strong when it's dry become a pathetic puddle of soggy tatters when it gets wet?

Paper is mostly made of cellulose, and that comes from the cell wall of plants. The plant cells use it as scaffolding to strengthen and protect their softer innards. Cellulose itself is just made of long chains of sugar – each link in the chain is one unit of glucose. Once you've extracted the cellulose from wood, what you've got looks like a plate of microscopic spaghetti. All you then do to make paper out of it is just squash it flat and dry it out.

No glue, no reinforcement... just a tangle of unconnected molecules. This sounds pretty weedy to me. And, as you stare at what is now apple puree on the road, it may seem as though there should have been better things to make the bag from. The question is not why it's weak now, but why it was so strong in the first place.

When it's dry, paper is incredible stuff: you can hang about 60kg from a piece of A4 paper without it breaking (if you're careful). That sort of strength is not to be sneezed at. And holding it all together is the same thing that holds water together – something called a hydrogen bond. The cellulose chains have lots of arms sticking out, each made of one oxygen and one hydrogen atom. The oxygen part tends to have a negative charge and the hydrogen tends to have a positive charge. When the cellulose chains touch each other, the positives in one attract the negatives in the other, and so the molecules form an interconnected network. This pull between hydrogen and oxygen is all that's holding your bag together, and it works because these hydrogen bonds are surprisingly strong.

Add water, and it all goes wrong. This is because water molecules also contain hydrogen and oxygen, and they bond in the same way, so they can sneak in between the cellulose chains. They surround the chains and push them apart, making the cellulose fibres swell by 15–20 per cent. As the cellulose molecules are moved away



“When it's dry, paper is incredible stuff: you can hang about 60kg from a piece of A4 paper without it breaking. That sort of strength is not to be sneezed at”

from each other, they no longer touch. The strong links are broken, so the chains just slither over each other and voilà, the apples are on their way to the floor. But if you get a paper bag wet and then dry it without pulling on it, those strong hydrogen bonds will reform, and the paper will be just as good as before.

So the humble paper bag doesn't have a permanent structure. More expensive paper bags have additives that bond the cellulose differently, and they keep their strength even when wet, but the bag from the local grocer is just a mat of tangled molecules. When water drips on to it, the tiny cellulose chains are shunted just enough to change the strength of the paper. They're far too small for you to see

what you're doing directly, but the larger-scale consequences are all too obvious.

Next time I go shopping for apples, I'll wait until it's stopped raining. ■

DR HELEN CZERSKI is a physicist, oceanographer and BBC science presenter whose shows include *Operation Iceberg* and *Orbit*

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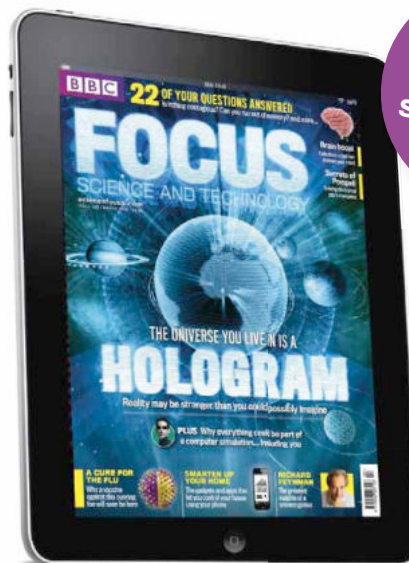
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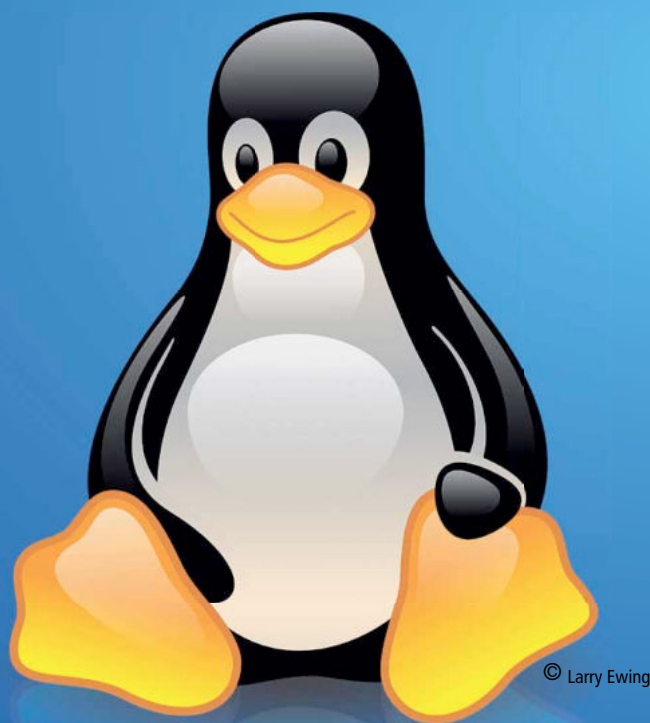
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UPLOAD YOUR BRAIN

Imagine a future where you can transfer your thoughts, emotions and experiences directly to the internet.

Rita Carter looks at how technology is starting to make this staple of science fiction a reality

YOU'RE FALLING FAST, the rush of wind pressing into your face as you free-fall towards the Earth. Only a few seconds ago you were in a plane, soaring 3km above the ground. Soon it's time to open your chute. You pull the chord and... phew! It opened, and it's time to experience the glorious landscape below.

But what if this experience isn't really yours? What if it was someone else's and you've merely downloaded the data from the internet directly into your brain? The idea that we could all one day share our thoughts, actions and emotions online has been dubbed the 'Mindscape' by the science fiction writer Sarah Newton. ➔

The ability to transfer your thoughts and emotions to the internet for others to experience might not be as far fetched as you might think



➔ “Barring some kind of major calamity I believe the Mindscape – a cloud-based database of human experiences – is pretty much inevitable. It will mark the next stage of our evolution as a species,” she says.

The Mindscape is just one of the big ideas being proposed by participants in the Hieroglyph project (see p54), but could it ever really happen? What does modern science have to say about the brain and how information and memories are stored? And would we even want to do it in the first place?

Experiences are created by the firing of groups of electrochemical nerve cells called neurones. Neurones fire in response to stimuli – light falling on the retina, for instance, or a chemical message from another part of the body. They send signals to one another along connective tendrils called axons, so a single stimulus can trigger activity throughout the brain. Different areas of the brain specialise in different things: those at the back are concerned with vision, for instance, while those in the front are about thinking, judging and feeling.

Modern imaging techniques, such as functional Magnetic Resonance Imaging (fMRI) make neuronal activity visible, so you can look at an active brain and deduce what sort of experience it is having. If someone is confronted by an angry person shouting at them, for instance, their brain will probably show activity in a little bit of deep brain tissue called the amygdala (fear); in a spot on the cortex behind the left ear (word comprehension) and in an area above the left ear (noise). Then there would be various other flurries of electricity – each one a different thought, emotion or perception triggered by the

“It should be possible to ‘read’ a person’s experience, encode it digitally and then ‘replay’ it in another brain”

event. Our ability to ‘read’ these signals is still pretty crude – you can tell if a person is looking at a house or a horse, but not precisely which house or horse. Undoubtedly, though, mind reading of this sort will get better as scanning techniques are refined.

Recall is simply the repetition of the neuronal patterns that generated the original experience. Most recollections are contaminated by neuronal activity related to the present moment, so the memory is vague and hazy and you never totally lose touch with the here and now. An intense recollection, however, such as the flashbacks that happen to people with post-traumatic stress disorder, is literally a ‘re-living’ of the original experience – you feel the same feelings, see the same sights, hear the same sounds and have no awareness of the present.

Given this, it seems that it should be possible in theory to ‘read’ a person’s experience, encode it digitally, then ‘replay’ it in another brain. However, there are several obstacles to overcome

before we can step into the Mindscape, and some of them may be beyond our current technological prowess. But that won’t stop scientists from trying...

The first challenge is technical: capturing someone’s experiences and memories in the Mindscape would mean recreating their brain in digital form and that is a vast undertaking. But this is already underway! The current effort to recreate a brain digitally is being carried out by The Human Brain Project (see left). The scheme is set to receive over €50 million from the European Commission over the next two years.

But even the team behind the project do not claim that they will be creating a sentient being. It is worth noting that its forerunner, the Blue Brain Project, took more than five years to reproduce a system equivalent to a cortical column in a rat’s brain – an ordered structure of 10,000 neurones. A human brain contains some 86 billion neurones, each one connected with hundreds or even thousands of others. But with continued advances in processing power, given time the goal could be achievable.

DIGITAL MEMORIES

The Mindscape idea would be technically much more difficult than the Human Brain Project. When you see a coloured-up diagram of the human brain with the functional areas neatly marked, it is easy to conclude that each brain is pretty much like any other. This is true on a macro level, but microscopically each brain is completely different and it is these differences that mould our experiences.

A simple stimulus – the sound of a pin dropping on glass, say – may trigger a billion temporal neurones to fire in my brain, and a billion different ones in yours. Some of mine might bring up memories associated with hearing a similar sound in the past; some may produce a visual image, others may stir the word ‘pin’ or ‘glass’ and so on. Yours will trigger different memories, different emotions, different words. One stimulus: two experiences.

To ‘map’ a person’s experience on to a digital brain therefore means that the artificial (or virtual) organ must be identical to the one in which the experience takes place, otherwise the result will be garbled. This involves working out every one of that brain’s minute distinctions. “The only way to re-create an individual’s brain would be to measure the exact topology of their neural connections – some 10^{14} of them – and then measure exactly how each brain cell fires in relation to all the others,” says artificial intelligence expert Igor Aleksander, Emeritus Professor of Neural Systems Engineering at Imperial College, London. “I’m afraid I’m a bit pessimistic.”

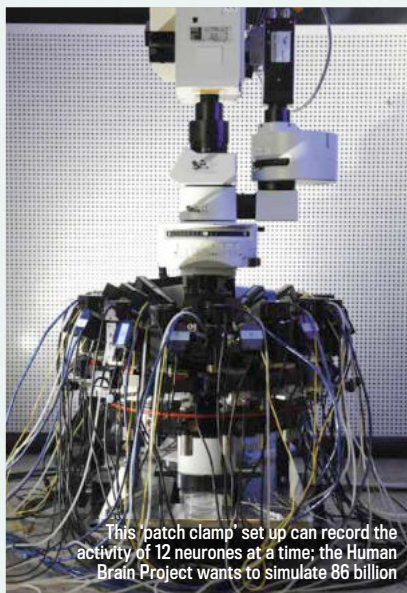
If that was all that was required to produce the Mindscape the idea could possibly be doable. But even if our memories could be stored in



WHAT IS THE HUMAN BRAIN PROJECT?

The EU’s flagship Human Brain Project will incorporate existing knowledge about the brain in supercomputer-based simulations. One goal is to provide a test-bed for brain disease. You could remove a particular brain circuit, for instance, then observe the effect – something that could only be done in a real brain by injuring it.

The Human Brain Project simulations are expected to learn, like real brains, and drive realistic behaviours. But it is set to be a monumental task. So far the most complicated brain we can map precisely is that of *Caenorhabditis elegans* – a worm with 300 neurones. A human brain has 86 billion. And architecture is only a small part of it. Even if we could put every neurone in place to make the model work like a real brain, we would have to know everything about every neurone right down to atomic level.

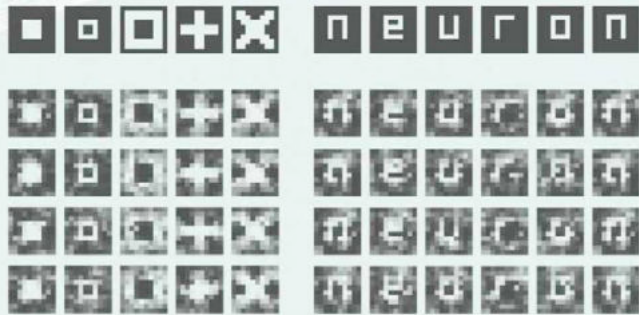


This ‘patch clamp’ set up can record the activity of 12 neurones at a time; the Human Brain Project wants to simulate 86 billion

UPLOAD YOUR BRAIN

A computer model from the
2005 Blue Brain Project
showing a single neocortical
column from a rat's brain.
Here 10,000 neurones
can be seen, which would
occupy a space just 1mm³

STEPPING STONES TO THE MINDSCAPE

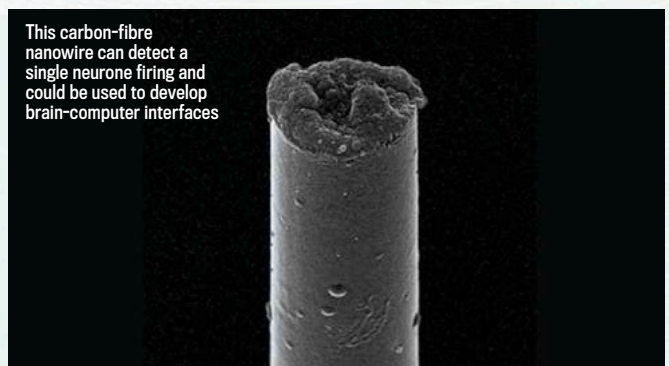


The symbols at the top were shown to volunteers in an fMRI scanner. Computers translated the data into the images below, effectively 'reading' their minds

SCANNING THE BRAIN

Modern brain imaging technology records localised neural activity. For example, fMRI does this by detecting changes in blood flow to different areas of the brain. This reveals, up to a point, what a person is experiencing because different parts of the brain 'do' different things. If the neuronal area concerned with physical form is active, for example, the person is seeing a shape. If the right amygdala lights up the person is feeling sad, or angry, or scared.

A few brain areas – like the visual cortex, for example – are now so well-mapped that the neural activity can be translated (by specialised software) into a precise experience. If the person is looking at a word, for instance, the computer can tell what it is, as demonstrated by Japanese researchers (results shown above). At the moment brain activity read in this way can only be described. To create the Mindscape, it would need to be turned into a subjective experience.



This carbon-fibre nanowire can detect a single neurone firing and could be used to develop brain-computer interfaces

PLUG YOUR BRAIN IN

Another way to 'read' a person's mind is to connect wires (or anything that conducts an electrical current) directly to neurones, then use the cells' electrical activity to drive an external device. Brain-computer interfaces are used successfully on people who are paralysed. A wire is connected to the motor cells that normally send signals to muscles and then, when the person thinks of moving, the signals from them are transmitted to a robotic limb.

In theory, a brain's entire cognitive function could be transmitted electrically, but not until there are some major advances in nanotechnology. The most advanced interface currently connects to about 200 neurones via two 4x4mm implanted electrode arrays. A brain with, say, 100 billion neurones would require an array measuring about 150x150m. Single carbon-fibre threads (pictured above) could reduce this to about one hundredth the size.

➔ digital form, there remains the problem of transferring them to a recipient's brain.

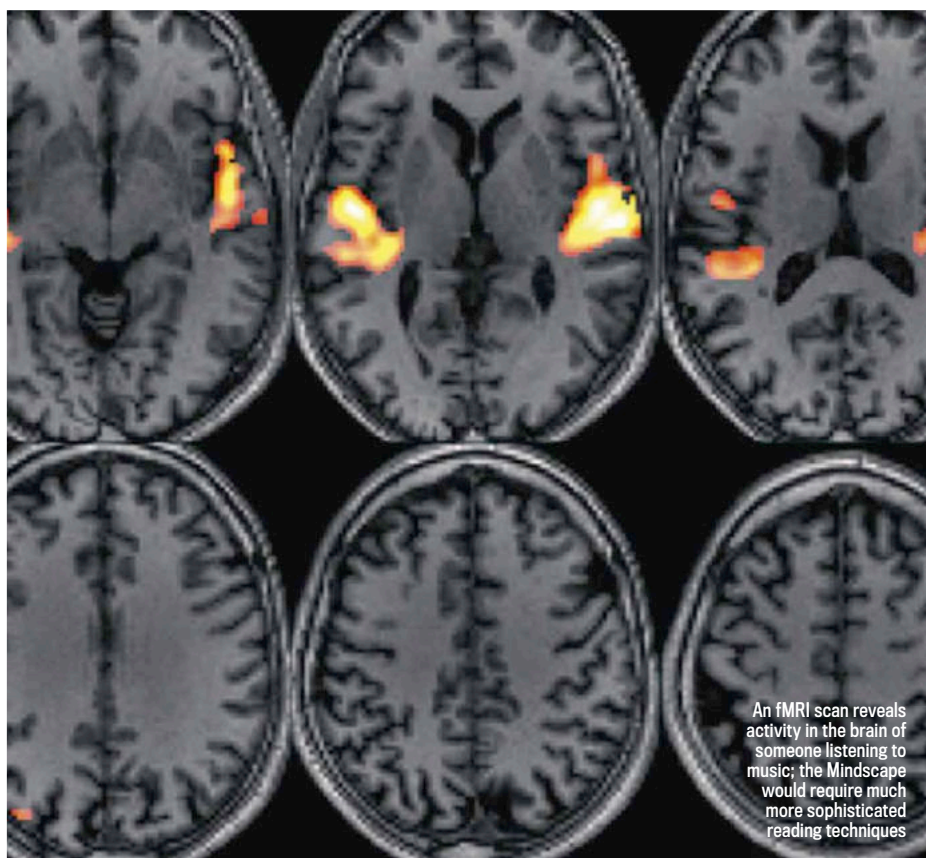
This is the really tricky bit. Just as the virtual brain has to be identical to that of the original experimenter in order to get a true copy of what they are going through, so the person who draws down the experience from the Mindscape must also have identical neural architecture. If they don't, the received experience will not be correctly 'mapped'. If, say, you transmitted the experience of something coloured blue to a brain deficient in blue-sensing neurones, the result might be a green experience, or no experience at all, or – who knows? – a vision of flying pigs.

It would not therefore be enough for the Mindscape to read the information from a person's brain and simply relay it. Rather the system would

"The system would have to interpret the original data, and reformulate it, like translating text"



A researcher studies fMRI scans of a brain – the technology is one of the best ways we can currently see what a person is experiencing



An fMRI scan reveals activity in the brain of someone listening to music; the Mindscape would require much more sophisticated reading techniques

have to interpret the original data, and reformulate it, like translating text.

Let's suppose that a technophile called Jane is in an art gallery in Italy. She looks at a painting of an animal and decides to transfer her experience to her friend Lara, in London. Both of them put on brain-reading devices – something like a very sophisticated EEG helmet – and the data from Jane's brain is transmitted to the cloud-based translator.

Jane's neural data shows that the painting first triggers activity in her visual cortex. This is transmitted along the neural pathway concerned with object recognition, where it is classified as 'dog'. Fine so far. But Jane once had a bad experience with a dog and the event created a pathway from the neurones that recognise 'dog' to her amygdala, the part of her brain that feels fear. As she looks at the painting, the activity from the object-recognition pathway therefore zooms off down the old path and produces fear.

Lara, on the other hand, does not have a connection from the 'dog'-recognising pathway to her amygdala. In fact she loves dogs, so were she to see the painting first-hand, her neural activity would whizz from the object-recognition pathway to her pleasure circuit. Given that the Mindscape is about transmitting experiences, not stimuli, the signal it would send would include Jane's amygdala activity as well as her sight of the painting.

So here we have a problem: the sight of the painting would normally produce

“Even if our memories could be stored in digital form, there remains the problem of transferring them”

pleasure in Lara, but the Mindscape is feeding in fear. This would not replicate the precise experience of Jane, though, because Lara would surely be puzzled by her own, unfamiliar reaction, whereas Jane's original experience would not include puzzlement at all.

The only way around this would be to alter Lara's entire self-identity. The information beamed into her would include all Jane's active memories down to every physical detail. It would be a full-on hallucination. Furthermore, even when it ended, Lara could not just go back to being herself because the experience will have altered her brain. She may have retained her happy response to dogs, but she will also, potentially at least, have Jane's fearful reaction. A little bit of her will have become Jane.

A more modest proposal is to create a receiver that can extract



A FUTURE OF UPLOADED MEMORIES

Peter J Bentley, the virtual memory pioneer, reports from the year 2075

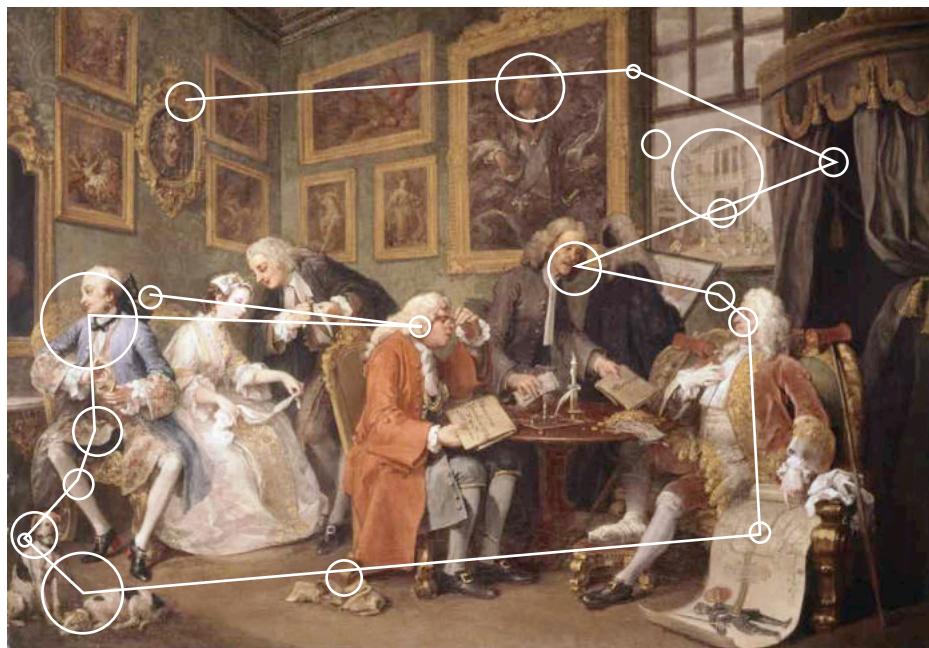
“ AH YES, MEMORY uploading. I first heard about it back in 2013. Sounded like my kind of thing so I really went for it. Every second, every minute of every day, awake or asleep, stored in a perfect digital record. I can relive every past moment like watching a movie. I can see the face of my wife the day we first met, experience our first kiss. I can watch the first steps of our little girl and see her smile in delight.

I soon got into the memory entertainment industry; I was one of the earliest memory editors who took the experiences of the stars and packaged them for mainstream consumption. With the proper controls, of course – you would not want to confuse their memories with your own! It's now a multi-billion-dollar industry with computer-generated memories able to simulate any experience you might want.

Of course my wife was also an early adopter. But she was insecure. She found my password and hacked me. She experienced every innocuous glance at a pretty girl, every laugh with a female colleague, but to her it was damning evidence. Ours was the first divorce based on memory evidence – soon after, memory trawling by the police was to become commonplace, and then the memory privacy laws were established.

So I can now look back on every moment of my life with perfect clarity. It's a curse. The final argument with my wife – if only I could take back those words... The time I carelessly insulted my sweet daughter, and the look on her face to which I was so oblivious at the time. I still wonder if my ex-wife dips into my memories from time to time. I wonder because I have a vague disquiet. Did I actually behave in that way? Was I really so bad? And why do I feel that there are some gaps, some good times that are no longer there? I wouldn't care so much but my biological brain passed away decades ago... **”**

Peter J Bentley is an honorary reader at University College London and the author of *Digitized: The Science Of Computers And How It Shapes Our World*



A study carried out by Loughborough University showed that people visiting the National Gallery only observed certain key details of a painting, as shown by the 'circles of interest' indicated on William Hogarth's *Marriage A-la-Mode: 1*

"Our experiences mainly consist of tiny bits of sensation 'filled out' by our imagination"

➔ and then relay only those bits of neural data that are related to sensational stimuli – the neural activity of visual neurones, say. So Jane's experience would be reduced to the sight of the picture, without the emotions and thoughts that accompany it.

But this would be a tricky task for many reasons. One is that what we think we sense is not what we actually sense. Experiments show that our experiences mainly consist of tiny bits of sensation 'filled out' by our imagination. One, carried out by Loughborough University, involved fitting eye-tracking devices to visitors at the National Gallery in London, and recording exactly where they looked when viewing a painting. It showed that they focused narrowly on areas of interest – faces, hands and the odd bright detail of clothes. Even when they looked for 10 minutes they neglected most of the canvas. When asked what they saw, though, all of them thought they had examined the entire picture – they had no idea that the parts they had really looked at were just a tiny bit of the whole.

This is typical of the way we view the world – we focus in on tiny areas of interest and ignore the rest. So although Jane may experience seeing

the whole picture in the art gallery, she will probably only register a few patches of it, and Lara would therefore receive something like a half-obliterated photograph. Jane would do better to snap the picture with a smartphone and transmit the image itself.

There is also no guarantee that a reading of neuronal activity associated with sensation would actually capture sensation. For instance, the visual neurones of blind people have been found to encode sound, so their activity can produce different types of experience. It is not even clear that 'visual' and 'auditory' neuronal activity produces conscious experience at all. Some studies suggest that perception only occurs when activity from sensory neurones is transmitted to other parts of the brain.

Whether or not the Mindscape is possible, it challenges our deepest ideas about identity and consciousness. If it ever is realised, the change to our lives would be dramatic. As Sarah Newton says: "It will be utterly profound. We're already becoming suspicious of the very concept of identity: it's beginning to become clear that, just as the mystics said, the self is an illusion." ■

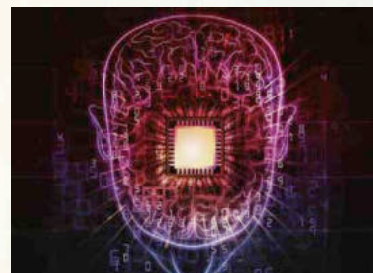
Rita Carter is a science writer and the author of *Mapping The Mind*

Find out more



www.bbc.co.uk/programmes/p014hby3

Listen to a BBC World Service programme on the Human Brain Project



FOR and AGAINST: Should we store all of our memories in digital form?



FOR

Sarah Newton is a science fiction author

Of course there are issues of free will, privacy and identity, but I think 21st Century Western humans already accept a vast amount of incursion into their psychic space – we're registered, recorded, monitored and observed, but generally we don't find it objectionable. The benefits generally outweigh the disadvantages. The gradual denudation of individual identity in favour of a more shared experience and consciousness that's now just beginning is our evolutionary destiny, and in the end we'll accept it.



AGAINST

Dr Stuart Armstrong, Future of Humanity Institute, University of Oxford

There could be mass unemployment among the thinking professions. Take the legal system – all you'd need would be the memories of some prominent lawyers and an efficient way to search those memories and thoughts. The searchers with slick presentation skills would inherit the Earth. Memory uploading would also allow dictators to identify people who oppose them. And busybodies would be able to judge your private life, making it harder to do things that are disapproved of but legal.



Would you be prepared to upload all of your thoughts and memories for anyone to experience?



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6



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a



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INTERVIEW

THE BIG IDEA IS BACK



ILLUSTRATOR: DANNY ALLISON

It's been decades since the last truly transformative technology came our way, but a group of US thinkers is hoping to change all that. We caught up with their leader, **Ed Finn**

TECHNOLOGICAL ADVANCES capable of transforming our lives used to come thick and fast. The 1950s alone saw the birth of nuclear power, jet aircraft, the Space Race and the computer. Today we're driving cars that are fundamentally the same as the ones we had 50 years ago, and no one has been to the Moon since 1972.

At Arizona State University, Ed Finn is aiming to change all that. He's the director of the Center for Science and the Imagination (CSU), which runs Hieroglyph – an online community where science fiction writers and scientists can share their ideas. It was inspired by author Neal Stephenson, who bemoans the “general failure of society to get big things done”.

Hieroglyph is already debating big ideas like the ‘Mindscape’ (see p44) and the best will end up in an anthology of stories to be published in 2014. We caught up with Finn to ask how fiction can change the world.

Why do you think now is the right time for the Hieroglyph project?

I think we're going through a phase where we have lost sight of the future. Or when we do think about it, we think it's something that scientists with white coats are dealing with. People think it's this pre-ordained, untouchable external rail that we're on and that we have no way of controlling it. That's totally wrong. A big part of this project is about fostering a stronger sense of urgency about the future.

How will the Hieroglyph project help?

The best way to get people thinking differently about the future is to come up with better stories about it. Neal Stephenson, the author behind this, likes to talk about how good science fiction can save hundreds of PowerPoint presentations and meetings because you get everyone to share the same iconic vision.

How are these visions being created?

Hieroglyph is an effort to bring science fiction writers together with scientists and engineers to collaborate on ideas and visions set in the near future and grounded in real science and technology. The project has a natural energy to it because science fiction writers and scientists have an affinity – there is a lot of mutual inspiration and admiration there. But there's also a natural tension because if you're a science fiction writer, you quickly run out of road in terms of actual science and you have to make a leap of imagination.

The book we'll publish, the science fiction anthology, will be the project's end point, with our authors writing the short stories that will be included. But the collaborations between the writers and scientists will be a major part of the project and that's where our website for sharing ideas becomes important.

“Hieroglyph will come up with a really inspiring vision for what we could do and therefore motivate people to take risks”

Is the Hieroglyph project borne out of frustration?

I think it's part of it. It's not that we have stopped innovating. A lot of innovation is taking place in the financial markets – not always to the betterment of mankind. In Silicon Valley, lots of brilliant, creative people are developing better algorithms for serving up ads or managing our social world. And we have seen incredible advances in those arenas. But part of this project is an effort to galvanise a response for more ambitious goals.

Could ‘health and safety’ get in the way of these big ideas?

That's always a challenge. That was a major factor in NASA ending its Shuttle programme. Hieroglyph will come up with a really inspiring and exciting vision for what we could do and therefore motivate people to take risks. They might try crazy things that may or may not work – hopefully not in stupidly life-threatening ways – but in adventurous ways.

Are scientists sometimes channelled into too narrow a field of research to think big?

I say this with a background in humanities, not science, but everything I understand about the current business of science is that there is an incredible focus on research boundaries that are tightly patrolled. There's a treadmill of grant applications that requires a deeply managerial approach to research.

This has its place but it's also important to give people a place to be creative. One of the writing guidelines for our stories is that a young scientist or engineer should be able to bring the idea to reality in their lifetime. We're hoping to reach young researchers and convince them that they can connect back to the child-like wonder that probably brought them into science in the first place. ■

Find out more

To read some of the Hieroglyph ideas, see <http://hieroglyph.asu.edu>

WHAT DO YOU THINK?

Has humanity run out of big ideas, or are we simply not adventurous enough in the 21st Century? Tell us at <http://twitter.com/sciencefocus> using the hashtag #bigideas

THE RESU OF TROY

With an arsenal of new scientific techniques about to be deployed in the ancient city, **Matthew Symonds** finds out whether we'll finally be able to separate fact from fiction

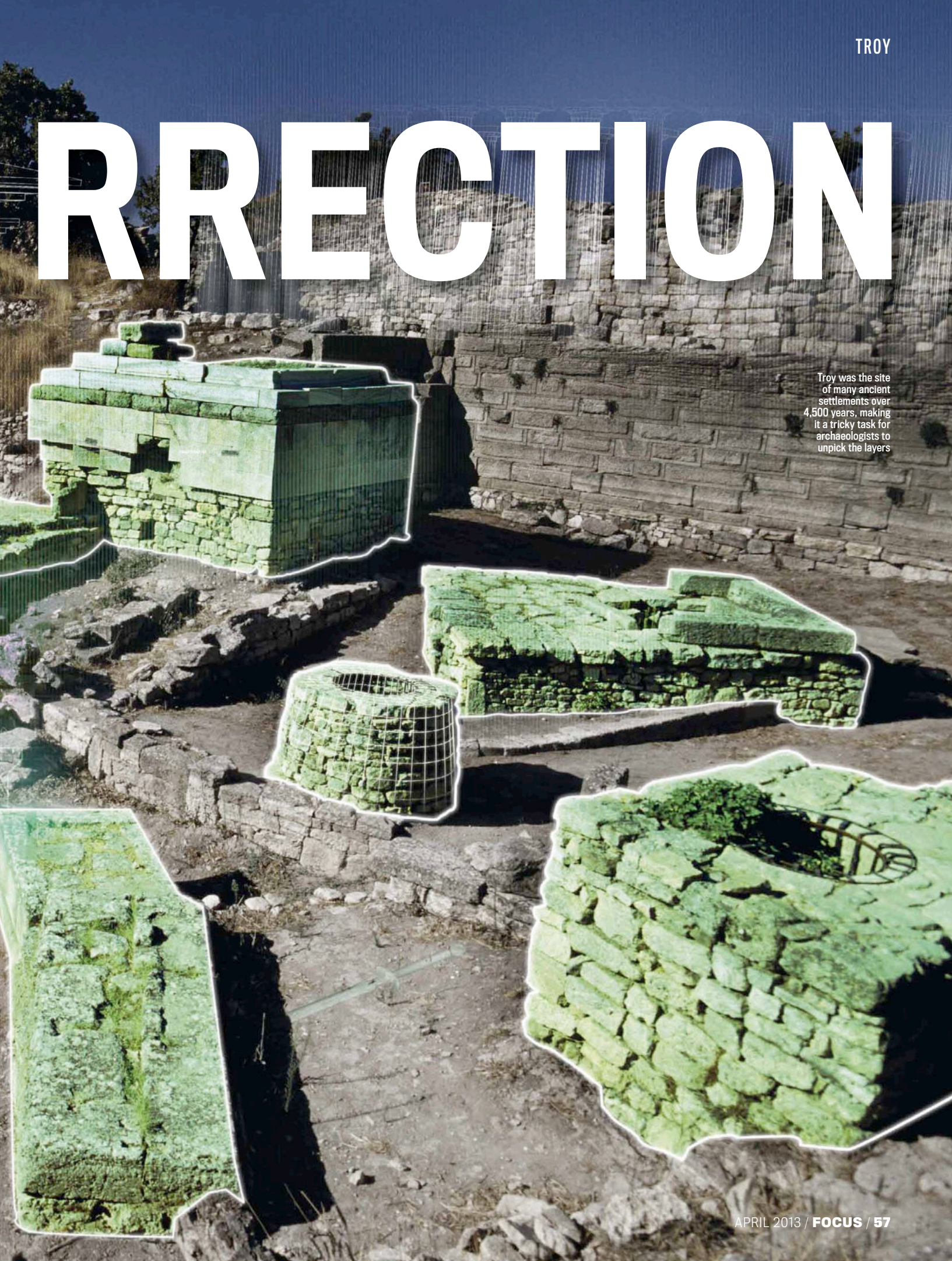
THERE'S PERHAPS NO place on Earth whose history is shrouded in so many tales and legends. Finding out what really happened at Troy has always proved problematic. But this summer, a new archaeological excavation will be combined with an arsenal of scientific techniques to bring the ancient palatial city, in what is now Turkey, back to life like never before.

It's hoped that advances in DNA sequencing and chemical analysis will provide the keys to unlock knowledge long thought lost. "What we have the opportunity to do at Troy is harness these techniques in a new way at a unique archaeological site," says Prof William Aylward at University of Wisconsin-Madison, who is leading what will be the most comprehensive dig



RECREATION

Troy was the site of many ancient settlements over 4,500 years, making it a tricky task for archaeologists to unpick the layers



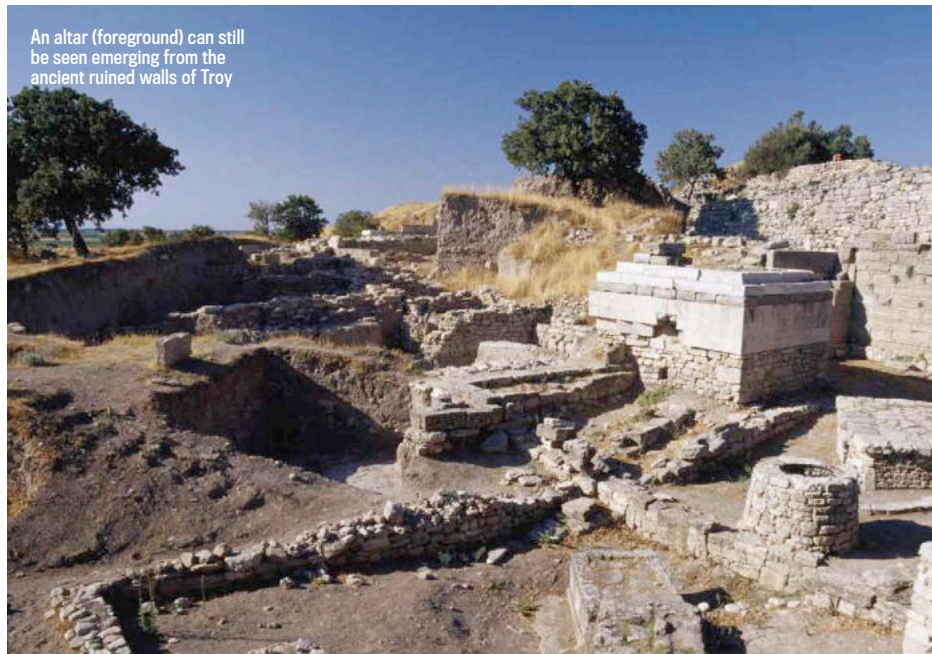
➔ at Troy since modern archaeology started at the site 140 years ago.

Troy is a laboratory like no other. This prehistoric city's violent death-throes echo through two of the greatest works of Western literature ever composed. Crafted by the poet Homer in around 750BC, these rare survivals from the ancient world portray a past that's captivated the imagination of generations. Early scholars attempting to prove the accuracy of Homer's accounts freely entwined archaeological fact with literary fiction. Divorcing myth from history is the Holy Grail of modern research at Troy. It's complicated by the fact that this is a complex archaeological site, with 10 cities superimposed on one another, some of which came to a violent end.

Homer's poems, the *Iliad* and *Odyssey*, were a phenomenal success in his own time. His tales were set around 400 years before his birth, harking back to the close of what archaeologists now call the Bronze Age. The poems tell of war between Greeks and Trojans, after a Trojan prince abducted a Greek king's wife. Following a decade-long siege, the city's defences were finally breached when Greek warriors were smuggled through its walls in the belly of a wooden horse. Troy was destroyed. But Homer was no war correspondent, so uncovering the truth in his tales remains the ultimate prize.

EARLY INVESTIGATIONS

Heinrich Schliemann is credited as the discoverer of Troy. This maverick German adventurer made the arduous journey to Anatolia, in modern Turkey, in 1868 with Homer in hand and a belief in the text that bordered on fanaticism. Once in Anatolia,



An altar (foreground) can still be seen emerging from the ancient ruined walls of Troy

Schliemann's attention was drawn to a modest hill known to the Turks as Hisarlik – meaning fortress – by the unassuming amateur archaeologist Frank Calvert. Excavations unearthed prehistoric ruins and spectacular treasures. Neither scholar, however, was the earliest person to deduce Troy's location. The Classical world had got there first.

Obsessed with Homer's poems, the Ancient Greeks and Romans were equally determined to locate Troy. They also identified the shattered Bronze Age ruins at Hisarlik, or Ilion as the site was then known, as Troy. The town developed a thriving tourist industry, allowing Roman visitors – including Emperors such as Augustus, Hadrian and Caracalla – to glimpse their mythical past.

When Ilion was finally abandoned, the settlement had been almost continually occupied for 4,500 years – more than twice the duration of any modern British town. This is one of the major draws for the scientists on the project, many of whom are bringing their talents to bear on archaeology for the first time. Troy's longevity should yield insights into the evolution of eating habits and even the development of a deadly disease – tuberculosis. “By connecting the scientific techniques and the unique nature of the archaeological site, I think we will provide added value for both areas,” says Aylward.

Only a small percentage of Troy's 20 hectares has been sampled, with the town's citadel receiving



TROJAN HORSE: FACT OR FICTION?

Will this summer's expedition turn up signs of this unlikely weapon of war?

According to Homer, the legendary wooden horse was dreamt up by the cunning hero Odysseus to spirit Greek warriors through Troy's defences. Modern scholars, though, are cautious about taking anything in Homer as fact. “Homer was an entertainer,” says Prof William Aylward. “The gap between archaeology and the Homeric retelling of the tale is irreconcilable.”

But there is archaeological evidence for conflict at the site. Excavations by American archaeologist Carl Blegen in the 1930s showed that the Bronze Age citadel

met a violent end in an era when the war that inspired Homer's works is likely to have raged. However, with even the basic question of whether the war as described by Homer actually took place, there are no plans to search for the wooden horse in this summer's excavations.

Ilion's Greco-Roman tour guides were rather less circumspect, happily showing visitors stretches of fortifications, complete with a gap where the wooden horse was supposedly towed through. They rounded off a visit by seeing where various Homeric heroes met their fates.



The wooden horse: probably won't be found this summer

TROY THROUGH THE AGES

Several cities have been built on the same site over the years

MAIN ARCHAEOLOGICAL LAYERS OF THE SITE OF TROY/HISARLIK

- TROY I
- TROY II
- TROY VI
- TROY VII
- TROY VIII-IX

NB: Troys III-V are unmapped and little is known about them



4,400 YEARS OF TROY

3100BC:

Troy I is founded when the first settlers construct a stone fortification wall. Research by scientists at Izmir University in Turkey has demonstrated that a large inlet came off the narrow strait linking the Black Sea and Mediterranean – and extended to the base of Troy, allowing it to control this key maritime passage.

2600-2300BC:

Troy II dates to around this period and was the focus of Schliemann's excavations. His reading of Homer led him to believe that the city of the Trojan War would be found crowning the bedrock of the site. This error led him to destroy the layers he was seeking, but did reveal stunning finds such as Priam's treasure (necklace pictured right).



2300-1800BC:

Troy III to Troy V spanned the Middle Bronze Age. This was a period of economic decline. There are signs of a recovery in Troy V, but it was not until Troy VI that the city flowered once more. For this reason no major new structures were constructed.

1700-1250BC AND 1250-1180 BC:

Troy VI and VII belong to the end of the Bronze Age. Most scholars believe that if the Homeric legends have any basis in fact, these are the periods they commemorate. Traces of destruction have been found to indicate that Troy met a violent end at the close of the Bronze Age. Could this be the result of a Trojan War?

700-85BC:

Troy VIII is the Ancient Greek city. At this time the citadel was refashioned, with a temple of Athena constructed at its highest point. A relief from this period is pictured below.



1BC-1300AD:

Troy IX belongs to the Roman period. Fascination with their Trojan heritage promoted a lively tourist trade, but by this period the town was stagnating economically. Silting was pushing the coastline further from the city, severing its access to the sea. Urban life was finally extinguished around the 13th Century AD.

TROY'S TREASURES

The site has turned up some remarkable finds



PRIAM'S TREASURE

By far the most celebrated discovery from Troy was found by German archaeologist Heinrich Schliemann in 1873. Consisting of spectacular Bronze Age gold and jewellery stashed in a copper

receptacle, nothing like this hoard had been found before. Belonging to Troy II (see 'Troy through the ages', p59), the artefacts dated to a far earlier period than their Trojan War-era name suggests – King Priam being the king of Troy during the Trojan War. In his autobiography, Schliemann says that with his wife looking on, he extracted the treasure at "... the most fearful risk to my life". He was concerned that the great fortification wall above where he was digging would fall down on top of him. Site notes, however, reveal that his wife was elsewhere at the time and, following the disappearance of the finds from Berlin at the end of the World War II, some suspected that the contents of the treasure had been faked. Their rediscovery in Russia's Pushkin Museum in 1994 vindicated Schliemann.



STONE AXEHEADS

Schliemann's final expedition in 1890 yielded a cache of finds that included four polished axeheads. With sharpened blades at one end and blunt hammerheads at the

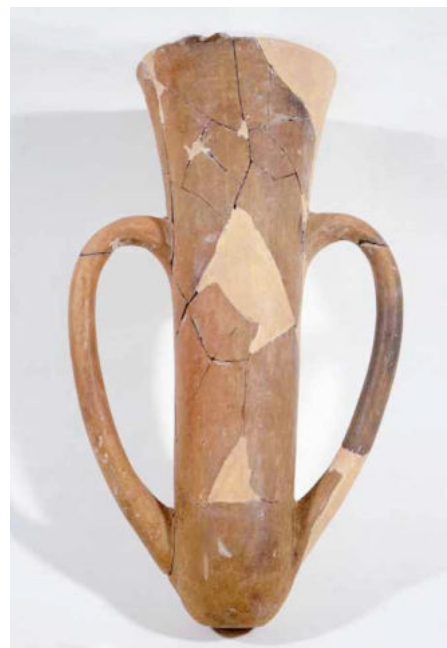
other, these beautiful, ornate weapons would have been fitted to a wooden handle and used in ceremonies.



BRONZE SEAL

This seal dates to the very end of the Bronze Age. It is currently a unique example of prehistoric writing from Troy.

Probably manufactured elsewhere and worn as an amulet and mark of identity, the hieroglyphs on the seal bear the name of the scribe and his consort.



A vase (left) dating from the time of Troy II in the 3rd millennium BC has a human form emerging, and a two-handled vase from the same period (right). Archaeologists are hoping to unearth more such discoveries this summer

→ the lion's share of attention. Home to the prehistoric city's most important buildings, even here major gaps in knowledge remain, including whether or not there was a Bronze Age palace. Extensive landscaping by the Ancient Greeks destroyed any traces of such a residence. But the joint team from the universities of Universities of Wisconsin-Madison and Çanakkale Onsekiz Mart University in Turkey are exploring other ways to determine the nature of life here.

"Anyone returning to Troy with an archaeological programme needs to look at what has not been found in previous campaigns. This includes prehistoric writing tablets," says Aylward. Such clay tablets were often inscribed with inventories recording the distribution of goods ranging from grain to chariots. They only survive if the archives were destroyed by fire, baking the tablets hard. Multiple phases of Troy's citadel were consumed by fire, however, making it entirely plausible that a cache of tablets awaits discovery.

The importance of finding direct written evidence detailing life in the prehistoric city would be hard to overstate. "If any part of the citadel provided evidence for an archive of the type that has been found at contemporary Mycenaean and Hittite palaces, it would transform our understanding of prehistoric Troy and provide substantial progress towards resolving the enduring question of the Trojan War," says Aylward.

"Another way to gain indirect access to the inhabitants of the citadel would be

through the Royal cemetery of prehistoric Troy," Aylward adds. "Dating to the heyday of the citadel at the end of the Bronze Age, these burial sites have yet to be found." They would not lie within the citadel itself, nor within the populated area of the prehistoric town. Instead the cemetery could be kilometres away, and its discovery will require detailed study of the town's hinterland.

FOOD FOR THOUGHT

Although the research will start in earnest this summer, Dr Greg Barrett-Wilt from the University of Wisconsin-Madison Biotechnology Centre has already spent a week on-site, scraping promising-looking samples from the surface of fragments of pottery. In deliberate defiance of standard archaeological procedure, these had not been meticulously cleaned after discovery. An expert on detecting the range of proteins present in a sample, Barrett-Wilt is hoping that these pot residues will reveal the Trojan diet, as no Bronze Age cookbooks survive.

"My expectation is that there is only a limited range of pottery types that you would expect to find proteins in – food preparation and consumption vessels, as well as storage containers," says Barrett-Wilt. "So if I can identify a protein bound to a piece of ceramic material, I can tell you unequivocally what has been in contact with that surface, be it sheep, goat, fish and so on. My ultimate goal is to make conclusive statements about

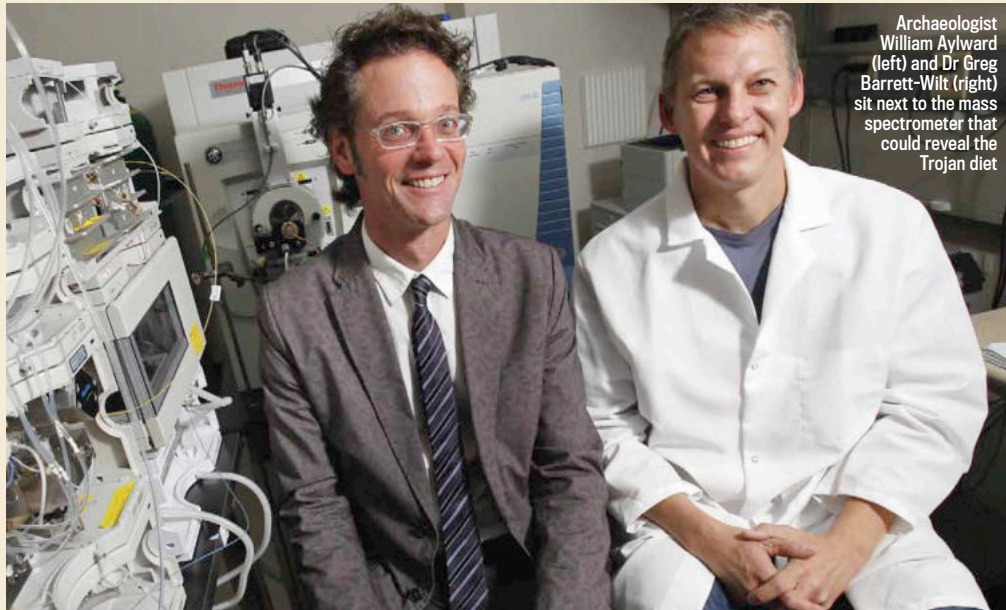
CLUES IN THE DUST

A technique used in forensic science and on Mars will shed light on Troy's past

Mass spectrometry has been used in everything from drugs development to space exploration – Curiosity, the mini-sized rover currently trundling around Mars, has a mass spectrometer among its array of instruments. Now this technique is being employed at Troy to wring the maximum amount of information from the site.

Wherever it's used, mass spectrometry identifies the component parts of a sample. At Troy, it is already being used ahead of the main expedition in the summer to identify proteins scraped from the outside of pottery so the ancient contents of these vessels can be determined.

Preparation for mass spectrometry began at the moment of the pottery's discovery, when the decision was taken not to scrub clean some pieces that appeared to have been used for food preparation or consumption. "I scrape off these surfaces, or where that can't be done I take a pair of pliers and just break off chunks, which we pulverise," says Dr Greg Barrett-Wilt (pictured right preparing a sample). This preparation produces a powder sample that is brushed into a tube. The proteins are then separated from



Archaeologist William Aylward (left) and Dr Greg Barrett-Wilt (right) sit next to the mass spectrometer that could reveal the Trojan diet



one another before an enzyme breaks the proteins down into their component peptides. They are then added to a mass spectrometer to be identified, revealing the nature of the proteins and therefore the foodstuffs remaining on the pottery.

"We're dealing with proteins that have been retained on the surface of these

pots, first during use and then during all the years in the ground," says Barrett-Wilt. "They have resisted being washed or abraded away. They've survived microorganisms and extremes of temperatures. So the proteins that remain are only the ones most resistant to being removed."

the foods that were consumed during daily life." It would be a major step towards reconstructing the prehistoric diet (see 'Clues in the dust', above).

As well as finding out how Trojans lived, Assistant Professor Caitlin Pepperell, an expert on the evolution of human pathogens, is looking at how they died. She is planning to use skeletal material from Troy to learn more about *Mycobacterium tuberculosis*, the bacterium that causes tuberculosis. A classic urban killer, tuberculosis thrives in dark, cramped environments – so it may have been prevalent in Troy.

"Ancient DNA is very different to modern DNA, because it has degraded over time," says Pepperell. "We break open the bacterium's cell with a chemical. As the amount of ancient DNA is much lower than in a modern cell, it has to be handled differently. The basic premise is that you try to extract the DNA sequence by amplifying it – reading parts of the

genome you know are there and then reconstructing the parts that are missing."

Pepperell's interest in Troy was piqued by a fragment of calcified lung from a tuberculosis sufferer who died in the city. "This is quite a special survival and we expect it to have good potential for DNA sampling," she says. Remains from soft tissue are scarce, and detecting other sufferers will be dependent on the tuberculosis being virulent enough to have permanently scarred their skeletons. "My ultimate goal is to gain an insight into the way tuberculosis and human populations have affected each other," says Pepperell. "I think the results from Troy will be very important for our understanding of the history of the spread of tuberculosis."

Caitlin will be one of several specialists who will be working on the human bone found at Troy. Meticulous modern study of the skeletal material can be expected to reveal new insights into the realities of life in the ancient town.

Adding modern techniques to the archaeologists' toolbox will secure insights that scholars such as Schliemann could only dream of. "The archaeological record is rich," says Aylward. "If we take a closer look with new scientific tools, there's likely to be much we can learn about the story of this World Heritage site."

Whether this expedition turns up evidence of the fabled wooden horse remains to be seen, but this is just the start of an exciting new era of discovery at Troy. ■

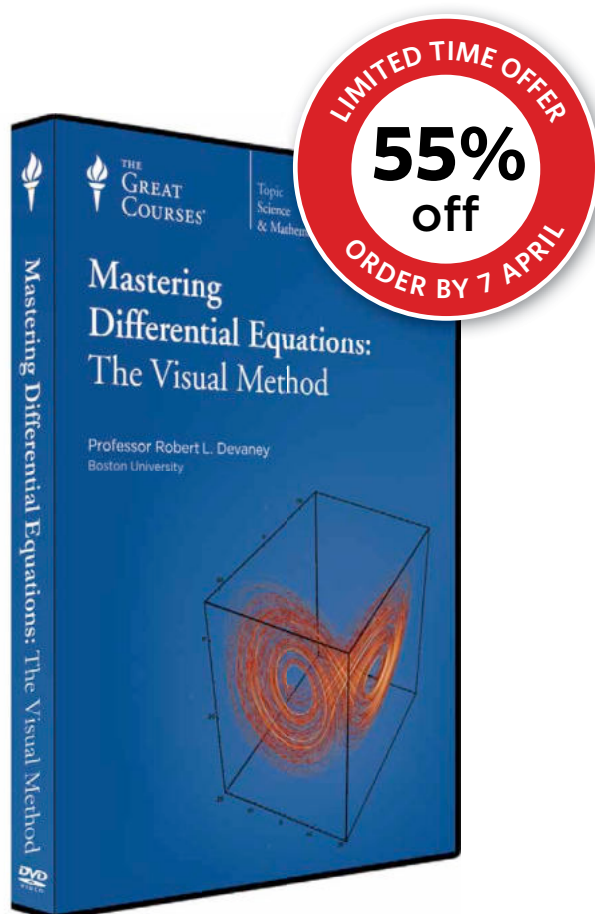
MATTHEW SYMONDS is the editor of *Current Archaeology* magazine

Find out more



<http://bit.ly/WDJBgD>

Watch the BBC Horizon show *The Truth Of Troy*



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5. Methods for Finding Explicit Solutions
6. How Computers Solve Differential Equations
7. Systems of Equations—
A Predator-Prey System
8. Second-Order Equations—
The Mass-Spring System
9. Damped and Undamped Harmonic Oscillators
10. Beating Modes and Resonance of Oscillators
11. Linear Systems of Differential Equations
12. An Excursion into Linear Algebra
13. Visualising Complex and Zero Eigenvalues
14. Summarising All Possible Linear Solutions
15. Nonlinear Systems Viewed Globally—Nullclines
16. Nonlinear Systems near Equilibria—Linearisation
17. Bifurcations in a Competing Species Model
18. Limit Cycles and Oscillations
in Chemistry
19. All Sorts of Nonlinear Pendulums
20. Periodic Forcing and How Chaos Occurs
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Q&A

YOUR QUESTIONS ANSWERED

BY OUR EXPERT PANEL



SUSAN BLACKMORE

Susan is a visiting psychology professor at the University of Plymouth. Her books include *The Meme Machine*



DR ALASTAIR GUNN

Alastair is a radio astronomer at the Jodrell Bank Centre for Astrophysics at the University of Manchester



ROBERT MATTHEWS

After studying physics at Oxford, Robert became a science writer. He's a visiting reader in science at Aston University



GARETH MITCHELL

Starting out as a broadcast engineer, Gareth now writes and presents *Digital Planet* on the BBC World Service



LUIS VILLAZON

Luis has a BSc in computing and an MSc in zoology from Oxford. His works include *How Cows Reach The Ground*

EMAIL YOUR QUESTIONS TO questions@sciencefocus.com

or post to *Focus Q&A*, Tower House, Fairfax Street, Bristol, BS1 3BN



If an ant gets too full of itself there's always a flick of the finger...

Q MELANIE SULLIVAN, COLCHESTER

How much weight can ants carry?

A AT LEAST HALF a gramme – which doesn't sound much, until you realise it's around 100 times an ant's weight. But we shouldn't feel too embarrassed about being out-lifted by an insect. Indeed, paradoxically it's because ants are so tiny that they have such impressive strength relative to their weight.

To see this, imagine an ant scaled up to be as large as a human. It would be around 300 times longer, while its increased volume would make its body weight around 10 million times greater. However, the strength of the ant's muscles depends on the number of fibres they contain, and thus on their cross-sectional area. So the 300x larger ant would have muscles only around 300² – that is, around 100,000 times stronger. So the human-sized ant may be much heftier, but its muscle strength hasn't increased to compensate, and it can barely lift its own body weight – just like us. **LV**

PHOTO: CATERS

Q GERRY FLYNN, ST HELIER

Is there a link between inoculations and autism?

A IN 1998, A team of researchers led by Dr Andrew Wakefield of the Royal Free Hospital, London, claimed to have identified a link between the behavioural disorder autism, bowel disease and the so-called MMR vaccine, widely used to protect young children against mumps, measles and rubella. The claim was based on a study of just 12 children, and had no known basis in medical science.

Even so, the seriousness of the implications, and the fact that the study had been published in the influential journal *The Lancet*, provoked headlines around the world. It also prompted many parents to refuse to have their children vaccinated, which led to a surge in cases of the diseases. In response to the furore, independent reviews of the evidence have been published internationally, the most recent covering almost 15 million children world-wide – and these have found no support for the original claim. **RM**

A child receives treatment for autism; there is no evidence to support the claim that it is caused by inoculations



In Numbers

32 million

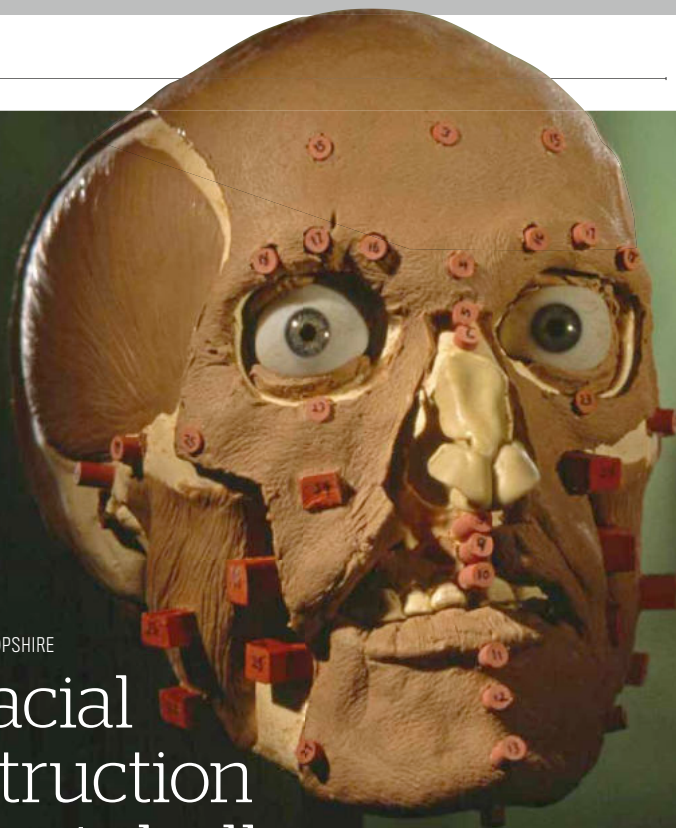
This is the number of individual bacterium estimated to live on every square inch of your skin.

Hopefully, this isn't the end result of a reconstruction attempt

Q RON GARDNER, SHROPSHIRE

Is the facial reconstruction of ancient skulls accurate?

A THE RELIABILITY OF facial reconstruction is controversial. With modern skulls, forensic facial reconstruction is only used as an aid to identify the victim and isn't admissible as evidence in court. The shape of the skull gives a lot of clues about the size and shape of the primary facial muscles, but there is still a lot of subjective judgement in reconstructing the ears and nose, as well as surface features like wrinkles, hair and expression. There isn't a standard methodology for facial reconstruction and two artists working from the same skull will produce different results. **LV**



Q SHERAZ DAD, BIRMINGHAM

Why do men tend to lose hair from the top of their heads?

A THIS PATTERN OF balding is called androgenic alopecia or 'male pattern baldness'. Hair loss typically begins above the temples where the hairline recedes and in a patch on the crown of the head or 'vertex'. Eventually only a rim of hair is left around

the back of the head. The chance of balding increases with age and the age at which it occurs is largely genetically determined. The hormone responsible is dihydrotestosterone, which causes the hair follicles to shrink and the hair to become thinner until the follicle goes dormant. But

why this happens in those specific areas is not understood. Although 95 per cent of balding in men takes this form, it is not always so. Hair can also be lost equally all over and in patches. **SB**

Let's face it, the 'combover' is not a cure

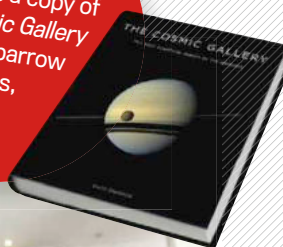


QUESTION OF THE MONTH

Going nowhere fast:
your subconscious
is more powerful
than you think

WINNER!

Matt wins a copy of
The Cosmic Gallery
by Giles Sparrow
(Quercus,
£19.99)



Q MATT TAYLOR, HORLEY

Why does it feel strange to walk up a non-working escalator?

A THIS IS CALLED the 'broken escalator phenomenon'. Each time we walk or ride on a moving escalator, our brains are learning to expect that escalators move. We then progressively fine-tune the motor control of our legs and the balance mechanisms of the inner ear to account for the motion. Even when we know that an escalator isn't moving, our conscious awareness of this isn't enough to override the unconscious

brain that recognises the grooved metal staircase as an escalator and therefore expects it to move.

Scientists at Imperial College London investigated the phenomenon in 2004 and found that walking on a moving platform just 20 times was enough to condition the brain to expect it to still be moving on the 21st attempt, even though subjects were told in advance that it would not be. **LV**



A computer can't produce a truly random set of numbers on its own

Q TIM DENNIS, SOUTHAMPTON

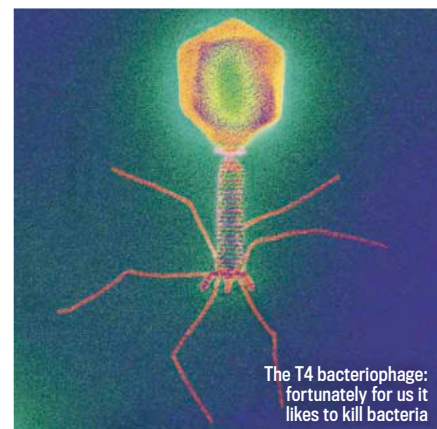
Can computers create random numbers?

A IN ITSELF, A computer cannot create a random sequence. It uses algorithms to produce an unpredictable series. These pseudo-random results are varied enough for most purposes. But creating true random numbers involves using unpredictable events like the time between decay events in radioactive sources. **GM**

Q KELVIN YU, MILTON KEYNES

Do germs have germs?

A GERMS ARE MICROSCOPIC organisms that cause disease, and they are indeed prone to diseases of their own. The Naegleria amoeba causes a form of encephalitis in humans for example, but the *Legionella pneumophila* bacterium (which causes Legionnaire's disease in humans) will also infect Naegleria. Even bacteria can be infected by certain viruses. The T4 bacteriophage virus infects *E. coli* bacteria and causes them to rupture and die after about 20 minutes. **LV**



The T4 bacteriophage: fortunately for us it likes to kill bacteria

TOP TEN LONGEST PREGNANCIES (LAND MAMMAL)



1. Elephant

21-22 months
Maximum birth weight: 120kg
Life span: Up to 80 years



2. Rhinoceros

16-18 months
Maximum birth weight: 65kg
Life span: Up to 50 years



3. Giraffe

15 months
Maximum birth weight: 75kg
Life span: Up to 25 years



4. Camel

13-14 months
Maximum birth weight: 50kg
Life span: Up to 50 years



5. Tapir

13 months
Maximum birth weight: 10kg
Life span: Up to 30 years



6. Donkey

12 months
Maximum birth weight: 25 kg
Life span: Up to 50 years



7. Llama

11-12 months
Maximum birth weight: 14kg
Life span: Up to 25 years



8. Horse

11 months
Maximum birth weight: 55kg
Life span: Up to 60 years



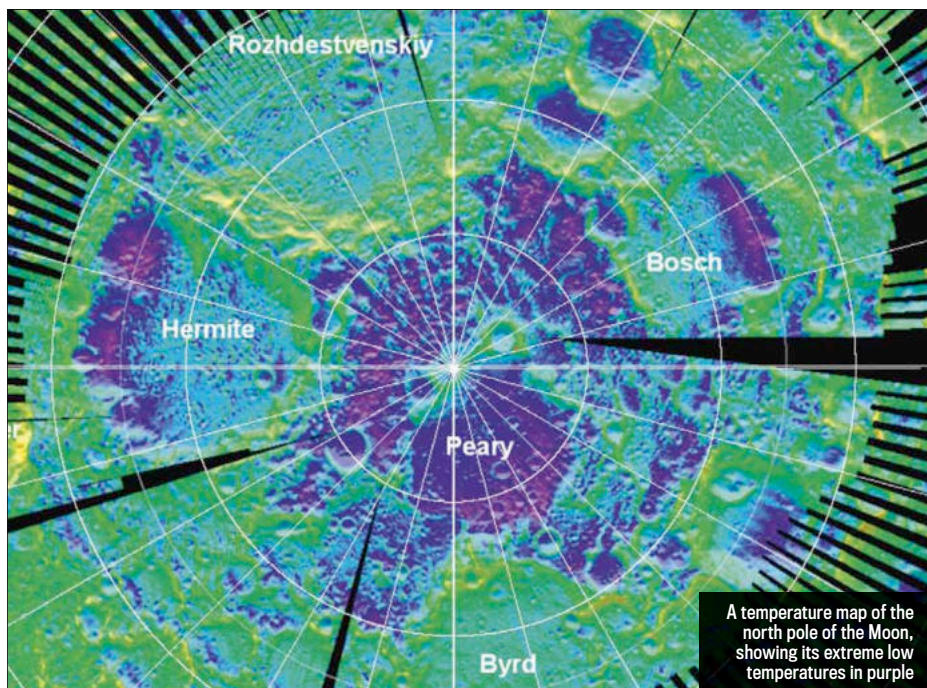
9. Cow

9-10 months
Maximum birth weight: 40kg
Life span: Up to 20 years



10. Human

9 months
Maximum birth weight: 7kg
Life span: Up to 130 years



A temperature map of the north pole of the Moon, showing its extreme low temperatures in purple

Q PAUL BARTELS, SOUTH AFRICA

What are the coldest places on the Moon?

A SURPRISINGLY, SOME AREAS of the Moon have been found to be the coldest in the entire Solar System. In 2009 the Diviner temperature sensor on board NASA's Lunar Reconnaissance Orbiter (LRO) measured the surface temperature of the Moon to be -248°C . This temperature was recorded on the southwestern edge of the floor of Hermite

Crater. Residing near the Moon's north pole, the floor of Hermite is permanently in shadow and receives next to no energy from the Sun.

Similar temperatures were found on the southern edges of the floors of the Peary and Bosch Craters. The staggeringly cold temperature in Hermite is well below that of the distant frozen dwarf planet Pluto at a minimum temperature of -230°C and the previous record-holder for the coldest place in the Solar System, Neptune's moon Triton at -235°C . **AG**

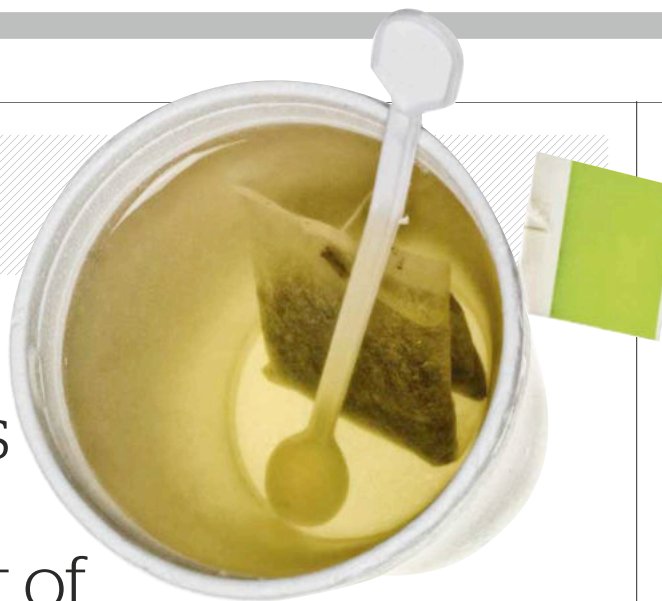
Q ROGER BRITTON, REDRUTH

How many humans were there when homo sapiens migrated out of Africa?

A BASED ON THE dating of stone tools found in Arabia and China, humans appear to have migrated out of Africa several times. No descendants from the early migrations survive today however, possibly because they were wiped out by the 10-year winter caused by the Toba supervolcano eruption around 73,000 years ago. All populations outside Africa today can trace their origin to a group of 150 to 1,000 humans that crossed the Red Sea around 70,000 years ago. The total human population in Africa at that time is estimated to have been 2,000 to 15,000. **LV**

Q JAMES CUTHBERT, READING

Why does tea taste wrong out of a plastic cup?



To get rid of substandard taste simply add seven sugars

A YOU MIGHT IMAGINE that the hot tea is dissolving something out of the plastic of the cup, but it probably isn't. In reality, the taste you perceive is influenced by a lot more than just the action of your taste buds, or even your nose; all the senses contribute. Crisps feel crunchier when you hear higher

frequency sounds as you eat, strawberry mousse tastes sweeter on a white plate than a black one and hot chocolate tastes better in orange cups.

We are conditioned to drink tea from ceramic cups and seeing it in a plastic cup primes us to expect substandard, vending machine tea. **LV**

WHAT IS THIS?



KNOW THE ANSWER?

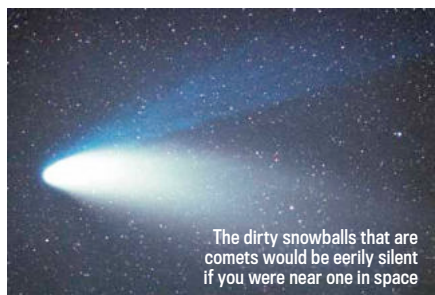
Go to sciencefocus.com/qanda/what and submit your answer now!

LAST MONTH'S ANSWER:

Well done to Mark Davies, who correctly guessed the GLACIER test facility.

Q BEN GOODWIN, LEWES

Do comets make a sound?



The dirty snowballs that are comets would be eerily silent if you were near one in space

A A FAMOUS MOVIE tagline chillingly reminds us that 'in space, no one can hear you scream'. This is true since for sound waves to be transmitted and eventually register as 'sound' in our ears, they need a medium through which to travel. That medium can be any material (solid, liquid or gas). Space is almost, but not quite, a perfect vacuum, so comets are silent, just like everything else in space. **AG**

? Did you know?

The Salyut 3 space station, launched in 1974, was armed with a 23mm cannon for defence.



Q DAVE RICHARDS, MANCHESTER

What are analogue TV signals used for now?

ANALOGUE TV BROADCASTS ceased in October 2012, freeing up spectrum around the 800MHz band. Ofcom is auctioning off the bandwidth to 4G mobile service providers. The 800Mhz spectrum is close to that of digital terrestrial TV, causing concerns that mobile base stations will interfere with set-top boxes. But mobile providers have set up an alliance called Digital Mobile Spectrum to monitor and limit the impact on television services. **GM**

Q CLARE MATTHEWS, CANTERBURY

Is tomato ketchup good for your heart?

TOMATOES AND TOMATO juice are known to reduce blood levels of low-density lipoprotein – or 'bad cholesterol' – and so reduce the risk of heart disease. But can a thick dollop of ketchup have any such positive effect? Apparently it can. The pigment that provides the red colouring in tomatoes is lycopene, an anti-oxidant that helps prevent cell damage and inhibits heart disease. Ketchup contains lycopene, with organic and dark red varieties containing the most. In some experiments people's levels of LDL fell in just a few weeks of eating extra ketchup. Whether it's as good as the real thing is another matter, since fresh tomatoes also contain many other healthy ingredients. **SB**



Rejoice! Ketchup can lower your cholesterol

Q FAITH TUTTON, BRISTOL

Why does arthritis hurt more when it's cold and wet?

A NO ONE knows why. Yet this connection has enough evidence to set clinicians wondering. The weather cannot affect the arthritis itself but might possibly make the symptoms worse. One theory blames the drop in barometric pressure associated with bad weather. The idea is that as pressure falls, tissues around the joints swell, rather like a balloon expanding when the air pressure drops. However, any such effect would be extremely small and has never been directly detected. Another theory is that people walk less and become stiffer in bad weather. **SB**



Cold weather seems to exacerbate the pain of arthritis

Q SAM SADEK, CAMBRIDGE

What's the most complex computer game?

Games like *World Of Warcraft* have 10 million users... and kung fu pandas



A MASSIVELY MULTIPLAYER online role-playing games like *World Of Warcraft* and *EverQuest* run on supercomputers, creating rich interactive environments for thousands of players at a time. *Eve Online* is often cited as the most complex. It has over 400,000 subscribers, governing a thriving economy across more than 5,000 star systems. **GM**

Q ROGER BRITTON, REDRUTH

Do all spiral galaxies have black holes at their centre?

A ALTHOUGH NOT CERTAIN, it seems very likely that most (if not all) spiral galaxies contain a supermassive black hole and sometimes more than one. That uncertainty exists for two reasons. First, we can't physically examine every spiral galaxy in the Universe to be completely convinced of that fact. Second, theory tells us that it isn't necessary for galaxies to contain central black holes – they will still hold together as galaxies without them. For many galaxies, however, black holes (or rather their

effects on their environments) are clearly observed in the turbulent core regions and the dynamics of their stars often indicate the presence of extremely massive objects.

There is also very strong evidence that black holes may be crucially important, perhaps even required, in the formation of galaxies in the early Universe. This would imply that indeed all types of galaxies (including spirals) contain a gravitational beast at their heart. **AG**



The galaxy NGC 1097 has a supermassive black hole that's 100 million times the mass of our Sun lying at its heart

Q STEVE RENSHALL, LONDON

Would a starving fat person live longer than a starving thin person?

A POSSIBLY. WHEN YOU stop eating, your body will exhaust the glycogen stored in the liver after about six hours and begin breaking down body fat into fatty acids for energy. But fatty acids can't cross the blood-brain barrier, so the brain needs another source of energy. Humans have a unique ability to convert fat into ketones to feed the brain. But a starving brain still needs about 10g of glucose per day and that has to come from muscle breakdown. A fat person will normally last longer, but 40 to 50 per cent weight loss is life threatening, regardless of your initial weight. **LV**



Being fat could prolong starving to death. Every cloud...



HOW IT WORKS

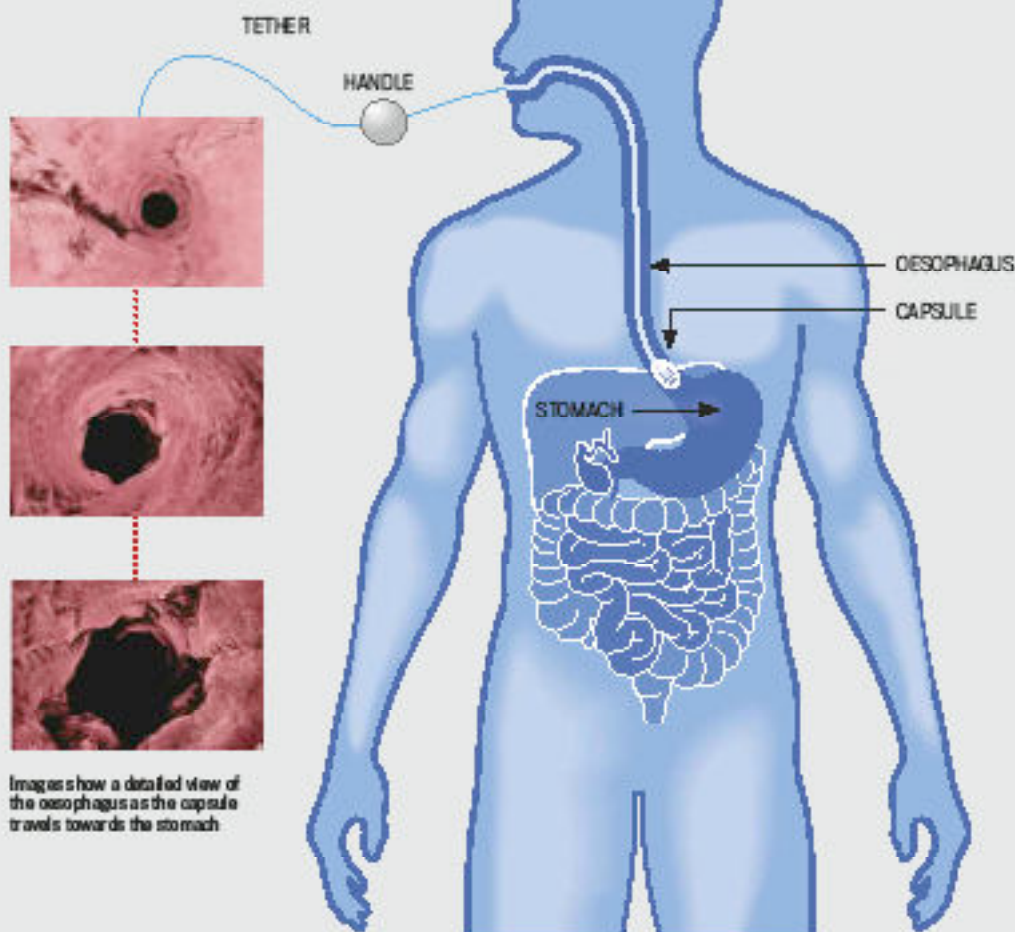
THE SCANNER PILL

DOCTORS MAY SOON have an improved method to scan the oesophagus, which connects your throat and your stomach, for disease. A capsule the size of a multivitamin pill captures three-dimensional, cross-sectional images in greater detail than you get with traditional high-resolution endoscopy. In addition, it doesn't require patients to be sedated.

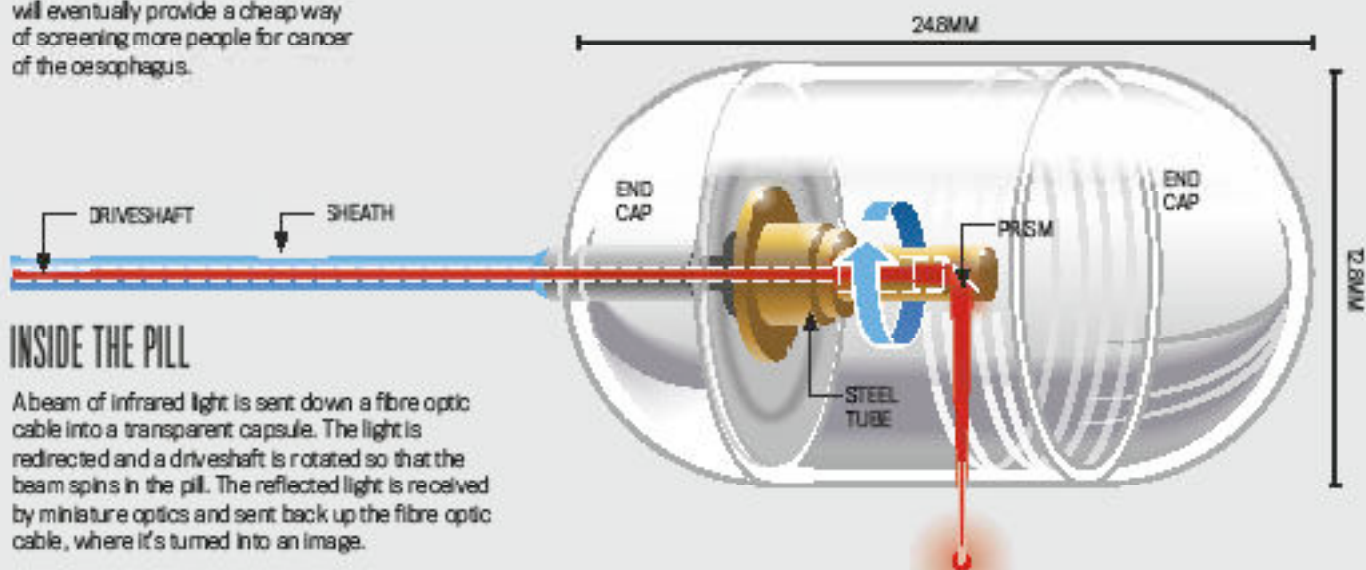
The pill contains a rapidly rotating laser tip that emits a beam of near-infrared light. Sensors in the pill record the light reflected back from the esophageal lining. The transparent capsule is attached to a tether that connects to an imaging console, allowing a doctor to control it.

After a patient swallows the capsule, it's carried down the oesophagus by normal contraction of the surrounding muscles. When the capsule reaches the entrance to the stomach, it can be pulled back up.

The capsule has been used in trials at Massachusetts General Hospital in the US. It's hoped that it will eventually provide a cheap way of screening more people for cancer of the oesophagus.



Images show a detailed view of the oesophagus as the capsule travels towards the stomach



INSIDE THE PILL

A beam of infrared light is sent down a fibre optic cable into a transparent capsule. The light is redirected and a driveshaft is rotated so that the beam spins in the pill. The reflected light is received by miniature optics and sent back up the fibre optic cable, where it's turned into an image.

THE NIGHT SKY: WHAT CAN I SEE IN APRIL?



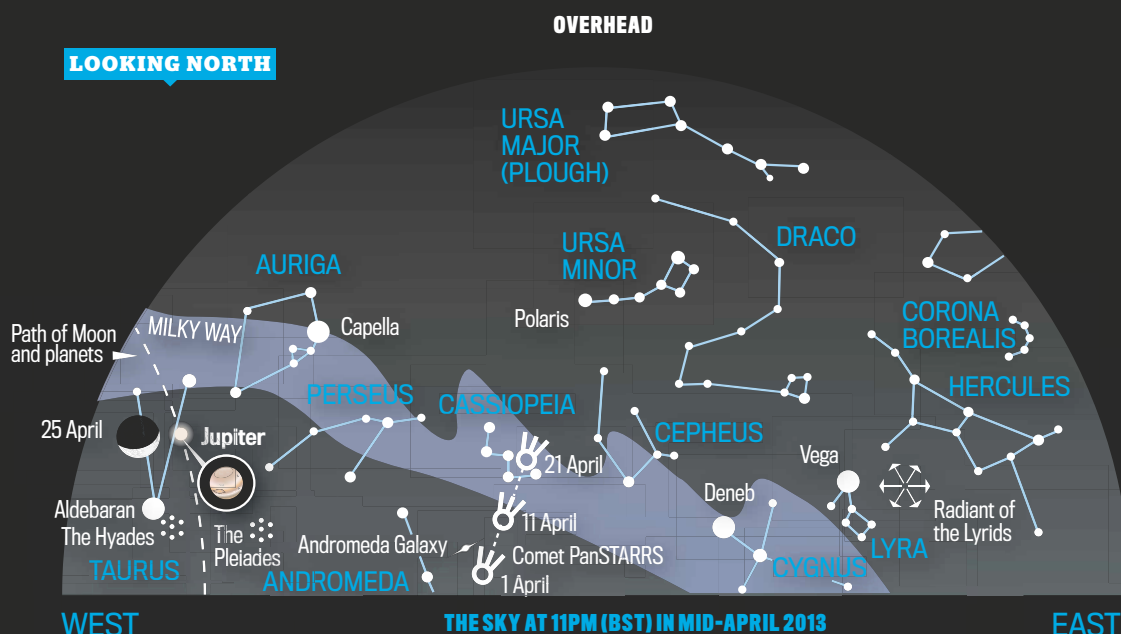
Don't miss *The Sky At Night* on BBC One every month
www.bbc.co.uk/skyatnight

Astronomy with
 Heather Couper
 and Nigel Henbest



APRIL'S SKIES ARE dominated by two constellations – Leo (which really does resemble a crouching lion), and Virgo (which bears no resemblance at all to a young lady!). Plus there are a couple of giant planets – Jupiter and Saturn – along with a meteor shower and a passing comet. The summer constellations of Lyra, Hercules and Cygnus are making an appearance in the east, while Orion and his companions tumble down to the western horizon.

LOOKING NORTH



LOOKING NORTH

All month, after sunset

Comet PanSTARRS moves past the Andromeda Galaxy and heads into the Milky Way. You might be able to see it with the naked eye early in the month and it should be a great sight with binoculars or a small telescope.

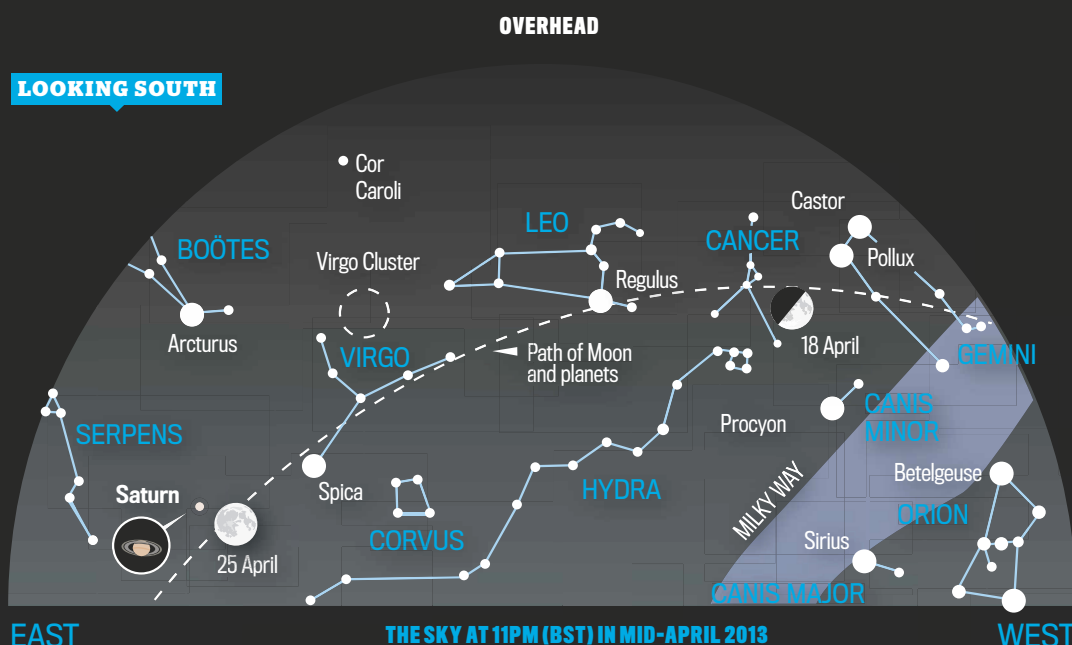
14 April, evening

Look to the northwest to see the crescent Moon cuddled up to the giant planet Jupiter. Below lie red giant Aldebaran, and the Hyades and Pleiades star clusters.

21/22 April: after midnight

It's the maximum of the Lyrid Meteor Shower, when the Earth ploughs into a stream of debris shed by Comet Thatcher. Perspective makes the shower appear to emanate from near Vega. It's not a good year: moonlight will interfere, and rates are low (10 meteors per hour, at best).

LOOKING SOUTH



LOOKING SOUTH

25 April: 9.08pm

This is a challenge! Tonight, we're treated to the 'best' lunar eclipse of the year – but don't hold your breath. The Moon moves into the Earth's shadow, but only 1 per cent of it is eclipsed.

28 April

Ring world Saturn is at 'opposition' – opposite the Sun in the sky, and closest to the Earth. Beg, borrow or steal a telescope to gaze upon this increasingly stormy world, circled by its incredible icy rings.

Find out more



Stargazing 2013

Discover astronomy with Heather Couper and Nigel Henbest (Philip's, £6.99)

Q LEN BAKER, LEICESTER

Why does grapefruit juice have an impact on drugs?

A GRAPEFRUIT JUICE IS widely regarded as a healthy, all-natural drink rich in vitamins C and A. But researchers have discovered that grapefruit juice affects the action of a human enzyme called CYP3A4, boosting the power of some drugs to potentially dangerous levels. Over 40 drugs are now known to be affected, including some used for treating blood pressure. **RM**

Grapefruit is bitter-sweet when it comes to mixing it with prescription drugs



Simply beautiful? Or is your appreciation an ancient genetic survival mechanism?

Q AARON HACON, NORWICH

What evolutionary advantage is there in finding a sunset beautiful?

A THERE'S A NUGGET of truth behind 'Red sky at night, shepherd's delight', because red sunsets are associated with settled high pressure systems that don't wash all the dust out of the lower atmosphere, and high pressure tends to mean fine weather.

But it would be a stretch to say that our appreciation of sunsets is a genetic weather-forecasting mechanism. Rather, we have evolved an aesthetic sense as part of the wider analytical faculties of our brain. Far from being skin deep, 'beauty' is a shorthand way of measuring the fundamental 'rightness' of a thing. In people for example, the attributes we find beautiful generally correlate quite well

with physical health or reproductive ability. Instead of evaluating all these different attributes independently, they all get rolled into a single measure: beauty.

The philosopher Dennis Dutton has suggested that the open rolling plains with occasional trees, that are so often represented in landscape art, are beautiful to us because they resemble the savanna of the Pleistocene epoch, when *Homo erectus* was first developing an aesthetic sense. Red sunsets would have been a familiar part of these landscapes and in an era when night was the most dangerous time, making sure you were safely back at camp to appreciate the last dying gasp of the day was probably especially important. **LV**

Did you know?

The only liquid you wouldn't drown in is oxygenated perfluorocarbon, because of the high amount of oxygen that can be held in it.



Q AMANDA GARDNER, HEREFORD

Is every snowflake really unique in shape?

A THERE'S LITTLE CHANCE of any two of the classic spiky six-sided snowflakes exactly matching each other in every detail. But that's not the only type of snowflake: some are far less complex – and two looking remarkably similar were found by American scientists on a collection plate aboard an aircraft in November 1986. **RM**

Q RICHARD O'NEILL, GLASGOW

How are woolly mammoths related to elephants?

A THEY BELONG TO the same taxonomic family, the Elephantidae, but have a different genus. Modern African and Asian elephants belong to the genus *Loxodonta* and *Elephas*, respectively, whereas the mammoth and woolly mammoth belonged to genus *Mammuthus*. This is roughly the same level of relatedness as between humans and gorillas. **LV**

Mammoths: not closely related to elephants



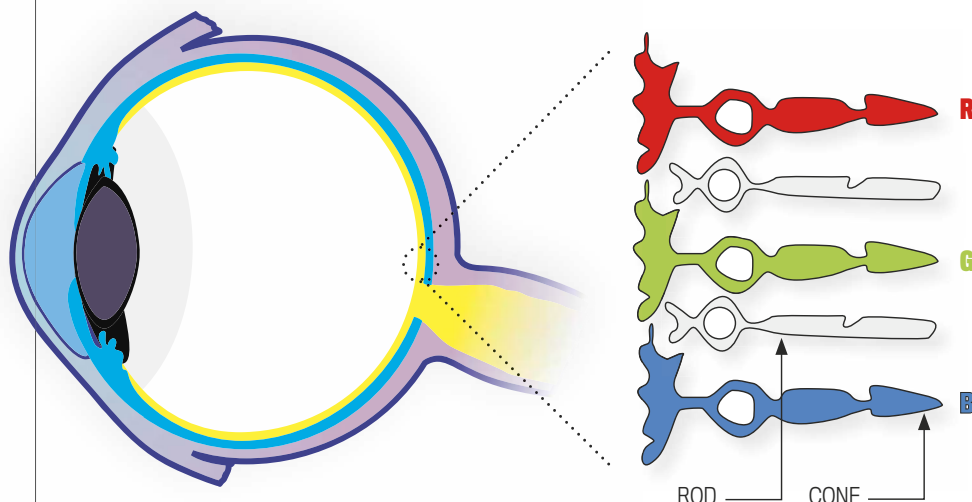
Q JOSEPH DEVINE, BY EMAIL

What causes colour blindness?

A MOST OFTEN IT'S the lack of one or more of the three types of cone cells, the wavelength-sensitive receptor cells in the retina. These are sometimes called red, green and blue cones, but more accurately are long, medium and short wavelength cones. Most people with normal vision are trichromats and have all three types. Dichromats have only two of the three, usually confusing red and green. Monochromats are far more rare and have only one type. These conditions are inherited, with about one in 20 men and

one in 200 women affected. This difference is because the damaged genes are on the X chromosome, and men have only one X chromosome. Women with a functional gene on one of their two X chromosomes are not colour blind.

Not all kinds of colour blindness are genetic. Diseases such as diabetes, Alzheimer's or Parkinson's disease can affect colour vision, as can alcoholism and some medications. Accidents or brain disease can also damage the parts of the brain that process colour. **SB**



Non colour blind range

Range if **RED** cones defectiveRange if **GREEN** cones defectiveRange if **BLUE** cones defective

Above: the range of colours an eye can pick up if it has various defective cone cells

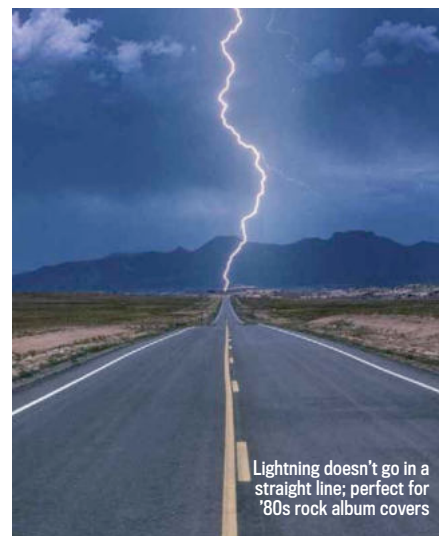
Did you know?

The city with the world's worst air pollution, according to a 2011 report, is Ahvaz, Iran.



Q LUKE AZZOPARDI, MALTA

Why doesn't lightning travel in a straight line?



Lightning doesn't go in a straight line; perfect for '80s rock album covers

A THE ZIG-ZAGGING path of lightning has its origin in processes still not fully understood. It begins with strong rising currents of air creating a static electric charge through frictional effects somewhat like those on the surface of balloons rubbed on suitable fabric. This charge generates an electric field that accelerates any free electrons in the surrounding air, smashing them into neighbouring molecules, thus releasing yet more electrons.

If sufficiently violent, these collisions will turn the air under the cloud from electrically insulating to conducting, which allows the passage of electrical current. This heats the air to around 30,000°C, triggering the characteristic flash of light that follows the zig-zag path formed by the collisions. That heat also causes a sudden expansion of the air, which we hear as a clap of thunder. **RM**

NEXT MONTH Over 20 more of your questions answered



For even more answers to the most puzzling questions, see the Q&A archive at www.sciencefocus.com/qanda

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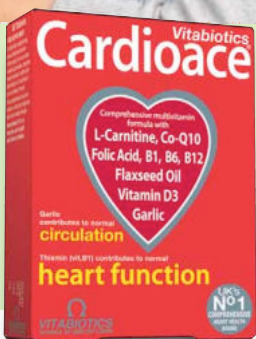
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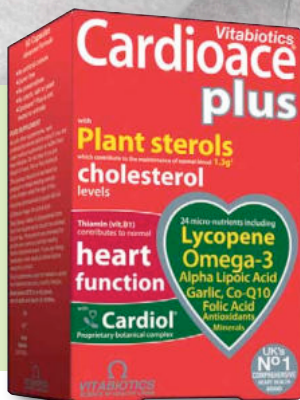
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CHAOS REIGNS

Fifty years on, **Adam Kucharski** looks at the legacy of an incredible theory and how it's changing science today

THE MARCH 1963 issue of the *Journal Of Atmospheric Sciences* contained something extraordinary. Tucked away on page 130, between articles on jet streams and ice crystals, was a paper that would revolutionise how we think about predictability in nature. Written by meteorologist Edward Lorenz, it introduced an idea that would go on to challenge our understanding of evolution, ecosystems and climate change. Even 50 years later, Chaos Theory is still shaping how we look at science, from plankton populations to planetary orbits. Yet Lorenz's discovery started with an accident.

Early in 1961, Lorenz had been working on simulations of

weather patterns. At the time, most forecasts were based solely on past observations, without accounting for the physics of the atmosphere. Lorenz wasn't happy with this approach, and wanted to see how predictable weather processes really were. To do this, he wrote down a set of equations to describe the movement of air in the atmosphere, and used a Royal McBee LGP-30 – one of the first desktop computers – to solve them.

Sitting in his office at the Massachusetts Institute of Technology (MIT), the breakthrough came when he looked at one of his results in more detail. Stopping the computer, he typed in a solution from earlier in the simulation and set things running again. When he returned after a coffee break,



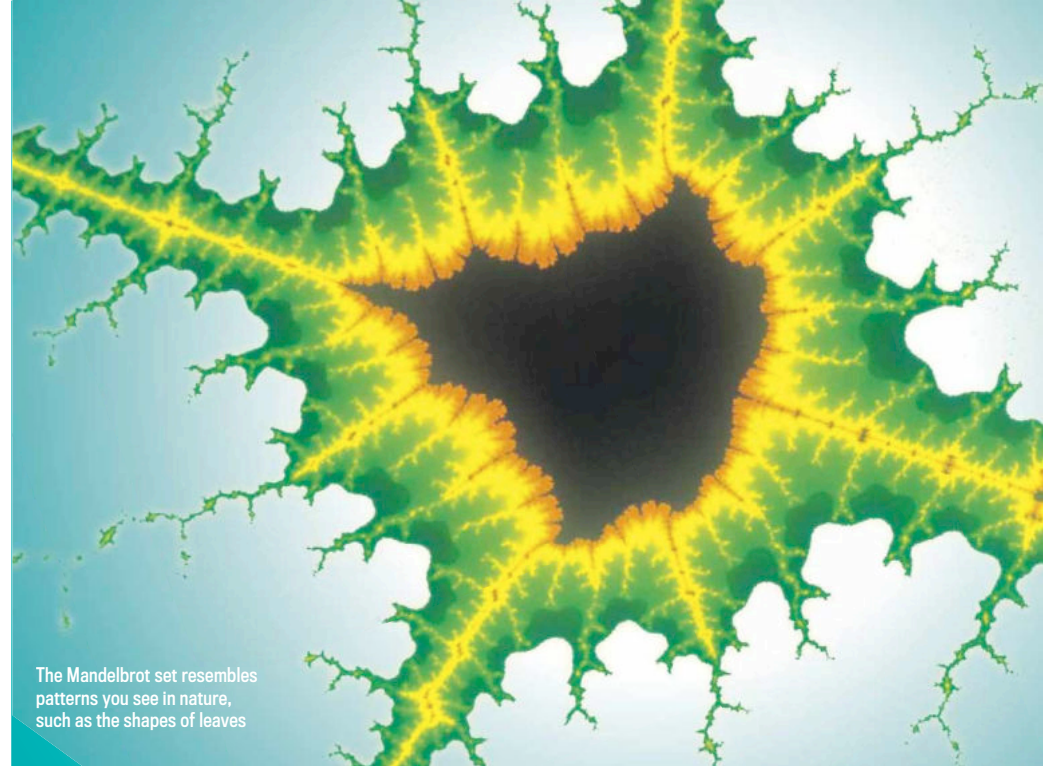


the computer had churned out the equivalent of two months' worth of weather data. But the new solution didn't match the old one. Lorenz compared the two results, and noticed that although they were initially similar, the differences became increasingly large over time.

He soon realised that the differences were due to a rounding error: the computer recorded results to six decimal places, but he had typed in the values to only three places. These tiny changes to the starting conditions of the simulation were enough to lead to very different results. The problem, known as 'sensitive dependence on initial conditions', was bad news for forecasters. "If the real atmosphere behaved in the same way as the model," Lorenz observed, "long-range weather prediction would be impossible."

Researchers had spotted the potential for the effects of sensitivity to initial conditions in the past, but they had not been fully aware of the implications. One hundred years earlier, Henri Poincaré, a French mathematician, had shown that the motion of three planets – each subject to the others' gravity – could not be described with simple equations. Meanwhile, Poincaré's colleague Jacques Hadamard had proved that trajectories along abstract mathematical surfaces, such as two-holed doughnuts, would be hard to predict. By showing that a real system might be impossible to forecast, Lorenz had managed to combine these earlier rough ideas into one remarkable insight.

The discovery also provided a possible explanation for observed climate patterns. Since his days as a weather forecaster for the US Air Force during the Second



The Mandelbrot set resembles patterns you see in nature, such as the shapes of leaves

“Economists needed to be aware that simple systems do not necessarily behave in a simple manner”

the air particles appeared to merge over time, forming a pair of intricate two-dimensional spirals. The shape became known as the 'Lorenz attractor', and its existence proved that a system could be unpredictable and yet elegantly ordered at the same time. Despite Lorenz's results grabbing the attention of meteorologists, it would be a decade before his ideas began to influence other areas of science.

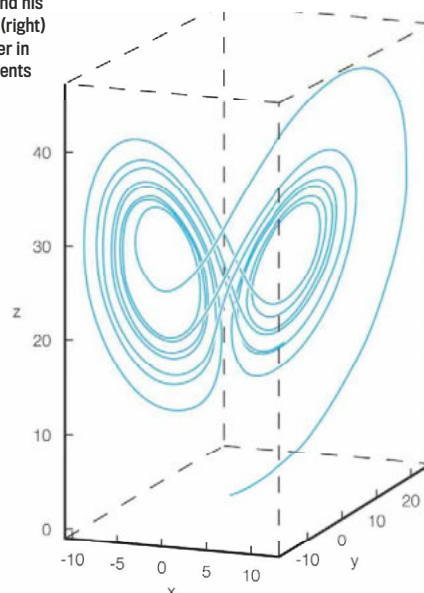
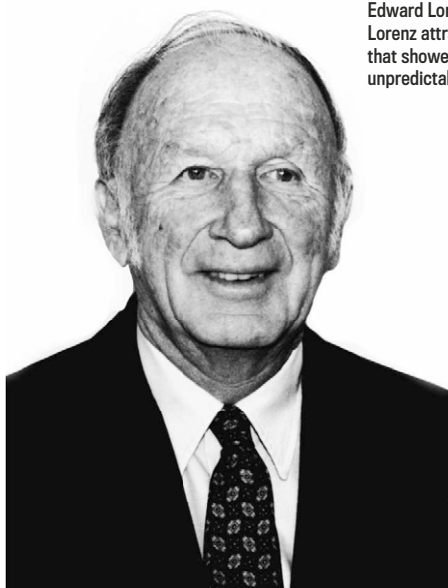
BEYOND WEATHER

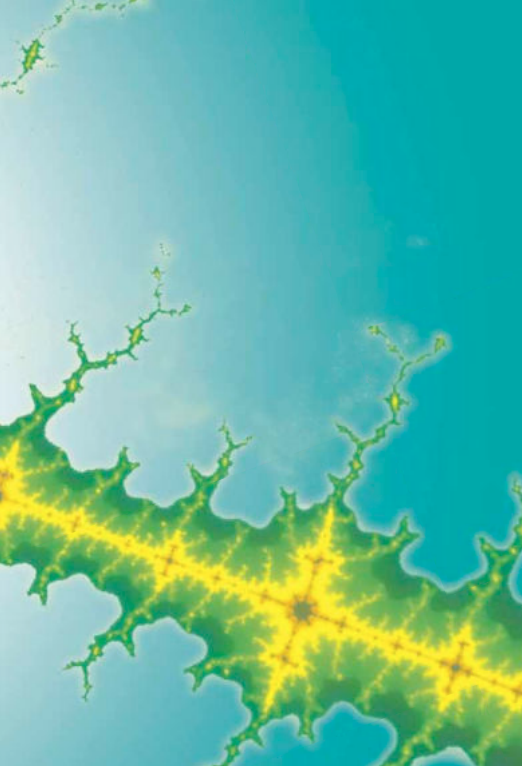
The University of Maryland mathematician James Yorke always carried a notebook to jot down problems. In the early 1970s, one of those was an equation that produced seemingly unpredictable results. Like Lorenz's model, Yorke's system was both sensitive to initial conditions – with two points starting near to each other before moving apart – and highly ordered: each point would end up tracing out the same 'attractor' over time. Yorke coined the term 'chaotic' to describe the equations with these properties, which made them predictable in principle but not in reality. As Lorenz later put it, chaos was "something that looks random but is not random".

During this period, Chaos Theory also attracted the attention of researchers from other fields. One of them was Robert May, a biologist at Princeton University. He suspected that some of the simple equations used to study ecosystems could produce more complicated results than previously thought. When May looked at them in more detail, he discovered that even the simplest population model – an equation known as the 'logistic map' (see 'Chaos in action' on p79) – was capable of chaotic behaviour.

World War, Lorenz had wondered why certain shapes appeared on weather maps more than others. Studying the results from his three-dimensional computer model, he noticed that the trajectories of

Edward Lorenz and his Lorenz attractor (right) that showed order in unpredictable events





As well as introducing Chaos Theory to ecology, May's work had important practical consequences. It was clear that biological systems could change in a very complicated way, despite following a basic set of rules. And if this was an issue in biology, why not in other fields too?

After his discovery, May pointed out that politicians and economists also needed to be aware that simple systems do not necessarily behave in a simple manner.

While May had been looking at problems in ecology, a mathematician at IBM's New York research centre had been studying other types of natural patterns. Benoît Mandelbrot was particularly interested in what he called 'fractals': shapes that looked as similar close-up as they did from afar. As he saw it, the world was full of fractals, from leaves and lungs to clouds and coastlines.

In 1979 Mandelbrot began a secondment at Harvard University, which he spent looking at the mathematics of fractals. He focused on the 'Julia set', a pattern that was generated by repeatedly applying a formula similar to the logistic map. Named after French mathematician Gaston Julia, the equations had sat dormant for nearly 60 years. Initially, Mandelbrot struggled, but when he decided to apply the formula using a computer, an intricate set of shapes emerged. Despite being completely new, they felt familiar to Mandelbrot. "It was as if somehow I had seen it before," he said.

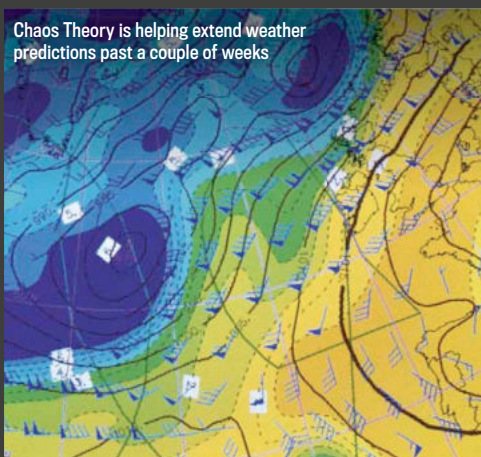
The surreal pattern, man-made and yet strangely natural, soon captured the public's imagination. Mandelbrot's work also helped address an important question about evolution. Since the time of Darwin, people had used the 'blind watchmaker' argument to suggest



HOW TO PREDICT THE FUTURE WITH CHAOS

The theory is being applied to areas as diverse as climate change, alien worlds and animal populations

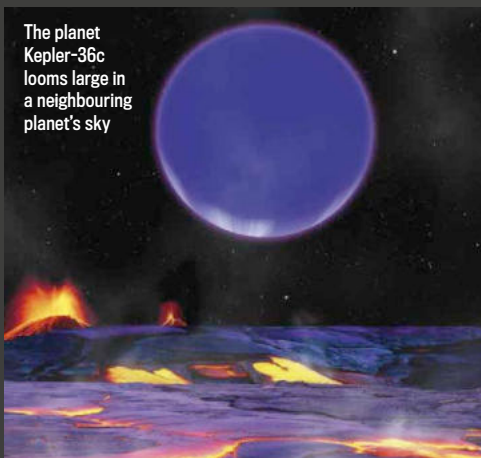
Chaos Theory is helping extend weather predictions past a couple of weeks



CLIMATE CHANGE

Even with huge computers, we cannot model the weather accurately for more than a couple of weeks in advance. So how can we estimate how the climate might change over several decades? In the last few years, researchers have used 'ensemble predictions' to improve long-term forecasts. These involve doing hundreds of different simulations, each with slightly different assumptions and starting conditions. Rather than obtaining a single prediction, researchers instead end up with a set of potential scenarios, each of which has a certain probability of happening. It is then a question of weighing the likelihood of an event against the damage it might cause.

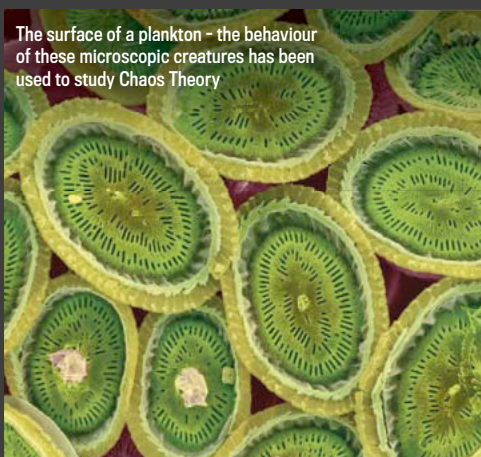
The planet Kepler-36c looms large in a neighbouring planet's sky



PLANETARY ORBITS

The Earth's orbit is chaotic, yet can still be predicted far into the future. Although a small change to the trajectory of our planet would eventually lead to a very different orbit, it would be millions of years before this sensitive dependence on initial conditions took effect. However, not all solar systems are as stable as ours. Last year, researchers at the Massachusetts Institute of Technology (MIT) found that the two planets in the Kepler-36 system have a much shorter window of predictability. In fact, simulations showed that a small change to one's orbit could lead to a noticeably different path within decades.

The surface of a plankton - the behaviour of these microscopic creatures has been used to study Chaos Theory



ECOLOGY

Biologists often use mathematical models to try and understand population patterns. But if the model is chaotic - as many are in ecology - it can be impossible to compare the simulation directly with the data. One recent solution is to use what are called 'summary statistics': features that capture the essence of the population dynamics. Examples might include how much its size fluctuates, or how often oscillations occur. By simulating a model with lots of different starting conditions and looking at the summary statistics it produces, we can decide whether the theory matches the main traits of the real system.

THE BUTTERFLY EFFECT

Rewind events and the precursor to a tornado could be a butterfly flapping in Brazil

LORENZ SHOWED THAT small changes in the atmosphere could have a dramatic effect on the weather. When he announced his breakthrough to colleagues, one of them pointed out that if his theory were true, a single flap of a seagull's wings could alter weather patterns forever. The seagull analogy gradually changed into a more poetic butterfly and a few years

later Lorenz gave a talk at a conference, asking, 'Does the flap of a butterfly's wings in Brazil set off a tornado in Texas?'

The 'butterfly effect' has since become a byword for anything that is highly dependent on initial conditions. Of course, the effect could take many forms: the butterfly may cause a tornado, or prevent one. All we know is that a world in which the

butterfly flapped its wings could end up very different from one in which it didn't.

Chaos Theory assumes that the world is 'deterministic': if we were to wind back time and start it running again with the exact same initial conditions, we would see the same result. However, if we don't know the precise starting conditions, the butterfly effect will eventually

ruin any predictions we make about the future.

Gathering more information will rarely fix the problem. Take a snooker ball: although it's fairly easy to estimate where it will go after hitting one cushion, with each extra cushion it hits we need to know far more about the original shot (not to mention the ball and the table) to predict what will happen next.

➔ that the world did not evolve, but was designed. They claimed that, like a pocket watch, nature is too complex to have emerged without the help of an intelligent creator. Mandelbrot's research, as well as that of Lorenz and May, proved that it was possible to produce complexity using incredibly simple rules.

Over the following two decades, Chaos Theory became a popular theme in biology. Inspired by May's work, researchers investigated chaotic behaviour in all sorts of systems, from food chains to epidemics. But there was a problem. Although biologists had shown that their models were chaotic, it was still not clear that the real world was. After all, how can we tell if something is actually random, or merely looks it? Despite ecosystems being full of seemingly unpredictable patterns, nobody had been able to find one that satisfied Yorke's definition of chaos.

The evidence finally came in 2008, when researchers at the University of Amsterdam published the results of a six-year plankton experiment. Although earlier studies had looked at the dynamics of insects and bacteria, this was the first time a complex food

web had been observed over a long period. The researchers found that the plankton ecosystem was sensitive to initial conditions, making it impossible to anticipate species numbers more than 15-30 days in advance (which is not far off the two-week limit for modern weather forecasts). They also spotted the other mark of a chaotic system: an 'attractor' that dictated how the species fluctuated.

Physicists found it much easier to test Lorenz's ideas. In fact, researchers had come across chaotic behaviour in the past – in neon lamps and electrical circuits – without realising what they were looking at. As Chaos Theory grew

“Researchers investigated chaotic behaviour in all sorts of systems, from food chains to epidemics”

in popularity, the challenge for physicists was to find examples of chaos in other places. The movement of heat in a fluid, which had inspired Lorenz's equations, seemed like a natural place to start. People had long known that when a tray of liquid was heated from below, it could suddenly begin to move in elaborate, unpredictable patterns. But it wasn't until 1978, when Albert Libchaber ran a series of experiments in his lab in Paris, that chaos was found to be the culprit.

While Libchaber's work explained the sudden change from a calm liquid to an unstable one, there is still much we still don't know about how fluids behave when they become turbulent. When Newton's laws are applied to the motion of a fluid, we end up with a set of formulae known as the 'Navier-Stokes equations'. These are widely employed across science and engineering: we can use them to look at airflow around a plane's wing, currents in an ocean, or even the weather. However, no one has yet managed to prove if solutions to the full set of equations – rather than a simplified version like Lorenz's – can actually become chaotic.

In fact, nobody even knows if the equations can always be solved. The

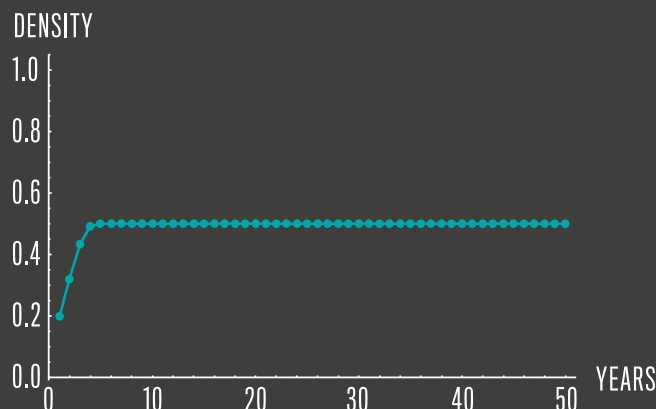
CHAOS IN ACTION

Even a population of flies shows remarkable behaviour

The graphs below show how a group of flies changes over time. The number of flies in a given area is the density – a number between 0 to 1. It's found by multiplying three other numbers: the population growth rate, the density in the previous year, and the amount of space (and hence food) still available. When the growth rate is high, chaos kicks in...

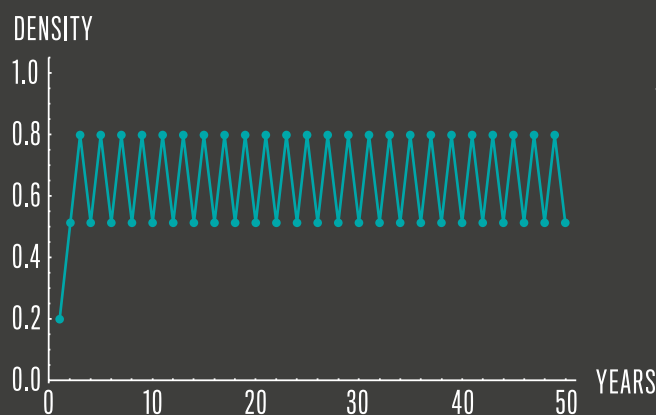
1. Equilibrium

If flies lay few eggs each year, the population will gradually settle down to equilibrium, with the same density each year. This value will be the same regardless of the initial density of the population.



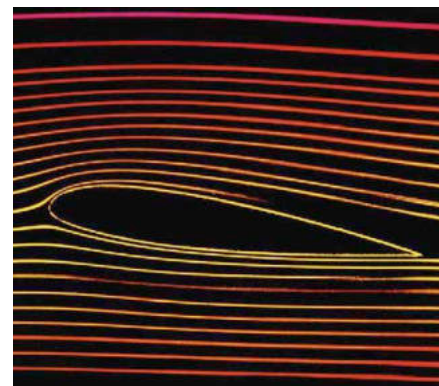
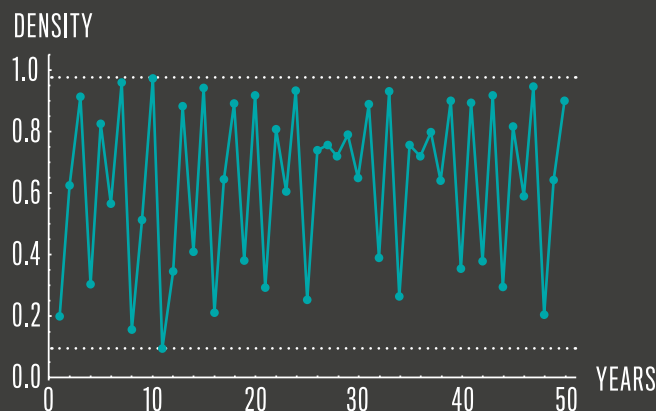
2. Oscillations

When the growth rate is larger, the population density will oscillate, from high one year to low the next. In some sense the system is still stable, as these two values remain the same over time.



3. Chaos

If the flies lay lots of eggs, the system becomes chaotic. Despite appearing to change randomly each year, the population actually fluctuates within a fixed range of values. Over time, it will trace out every number within this range.



The maths behind airflow hasn't been entirely cracked

problem is one of the most important in mathematics, with the Clay Institute offering \$1 million to anyone who can find an answer. Unravelling the Navier-Stokes equations would finally give engineers a proper theory for the behaviour of fluids.

WHAT NEXT?

As well as helping us explain natural patterns, Chaos Theory has sparked new questions. One of these is the problem of so-called 'self-organisation'. Why do seemingly chaotic groups of fireflies or neurones suddenly synchronise?

Chaos Theory has been a successful starting point, revealing the behaviour of simple equations, but many problems are now beyond the scale of this research. Fortunately, the search for fresh approaches has begun. For example, US researchers recently put together a map of the 'human microbiome', the community of bacteria and viruses that live within us. By studying these microbes as an interacting network, rather than as single organisms, it is hoped we will learn more about the internal co-operation that keeps people healthy, as well as the conflicts that cause disease.

Studies like this have demonstrated that if we want to predict how a complicated network behaves, we need to understand its structure. This means untangling huge numbers of interactions. Recent decades have been about making sense of chaos; now we must tackle complexity. ■

ADAM KUCHARSKI has a PhD in Maths and is an award-winning science writer

Find out more



Listen to Radio 4's *In Our Time*, presented by Melvyn Bragg, on chaos theory.
www.bbc.co.uk/programmes/p00548f6



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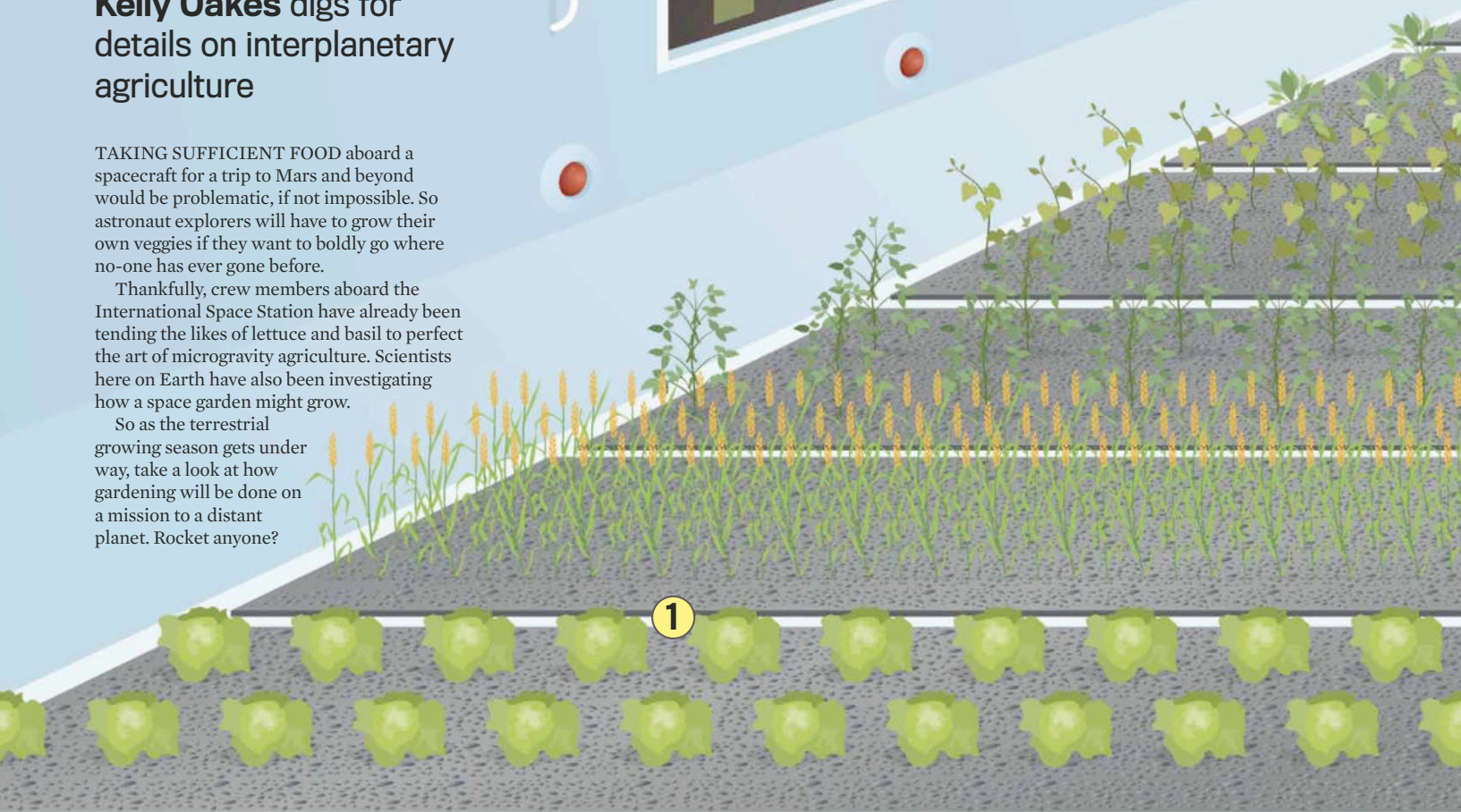
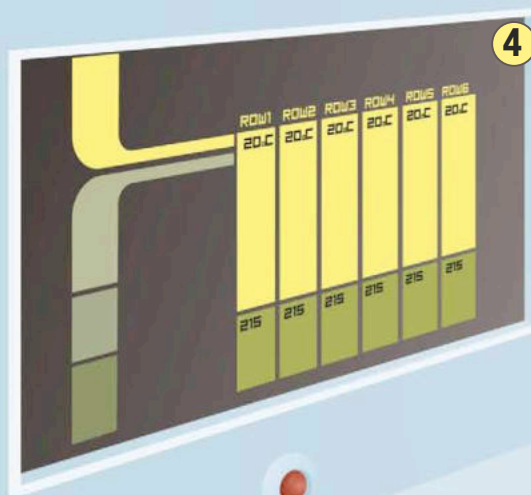
TO BOLDLY GROW

Kelly Oakes digs for details on interplanetary agriculture

TAKING SUFFICIENT FOOD aboard a spacecraft for a trip to Mars and beyond would be problematic, if not impossible. So astronaut explorers will have to grow their own veggies if they want to boldly go where no-one has ever gone before.

Thankfully, crew members aboard the International Space Station have already been tending the likes of lettuce and basil to perfect the art of microgravity agriculture. Scientists here on Earth have also been investigating how a space garden might grow.

So as the terrestrial growing season gets under way, take a look at how gardening will be done on a mission to a distant planet. Rocket anyone?



1 SOIL SOLUTION

Soil would get everywhere in space, so astronauts would need something else to grow their plants in. The best medium would be a porous material that can absorb water as well as nutrients, says Dr Anna-Lisa Paul, a plant scientist at the University of Florida. "Porous materials can absorb nutrients so they don't float all over the place," says Dr Paul.

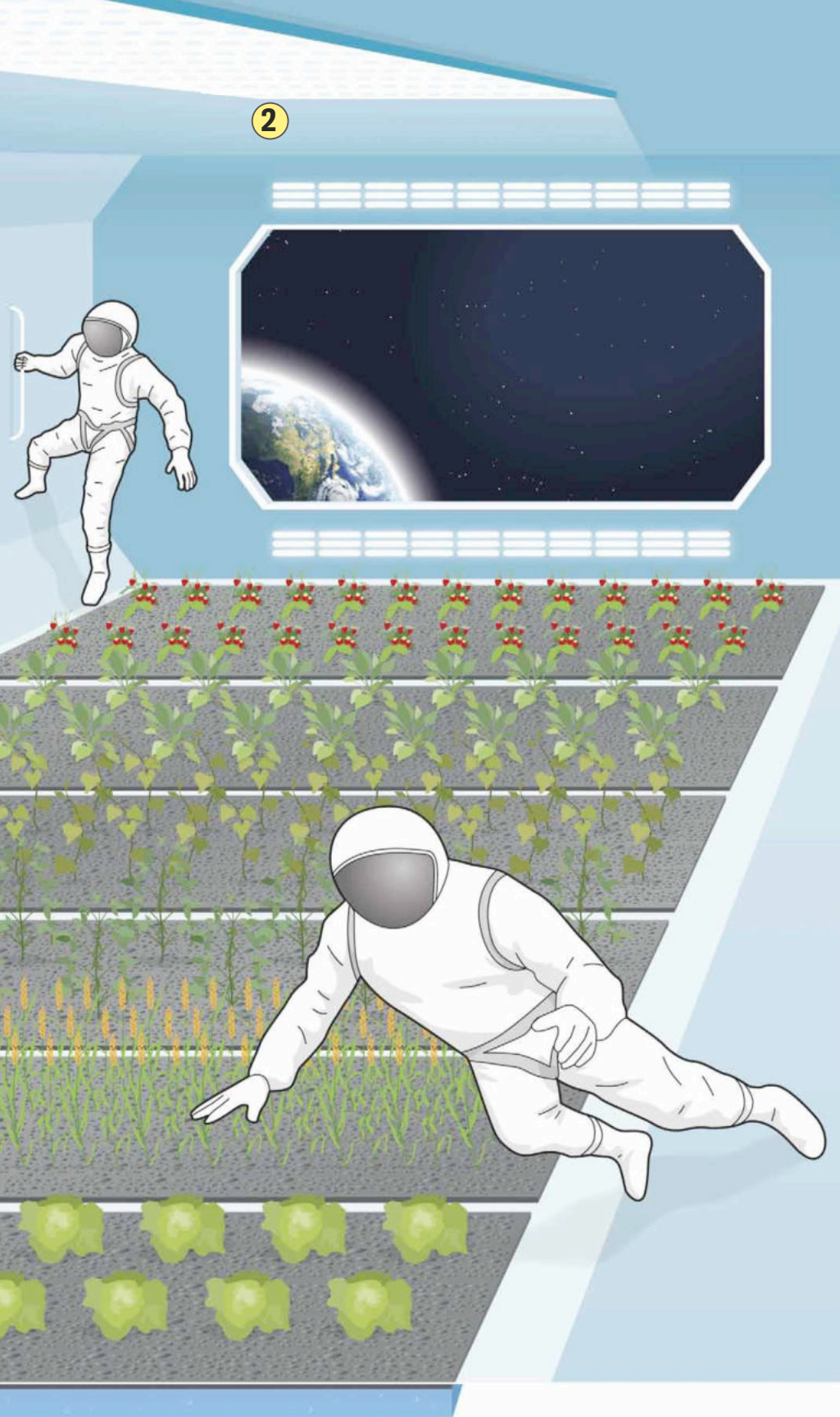
2 LET THERE BE LIGHT

To give plants light, LEDs provide the most control. "You can tune the LEDs specifically to the wavelength of light the plants need most," says Paul. Sunlight is also an option for journeys as far as Mars. It doesn't cost anything, but does mean extra weight because you'd need something, such as fibre-optic cables, to direct the light inside the spacecraft.

3 WEIGHTLESS WATERING

Setting up a garden on the Moon or Mars would be easier than on a spaceship. "If you have some gravity, you can use conventional watering techniques," says Dr Ray Wheeler at NASA's Kennedy Space Center. But in the weightlessness of space, water would float around. This is where a porous material comes in, providing both water and nutrients to the plants.

2



4 SENSE AND CONTROL

"If we send a small growing chamber to the International Space Station (ISS), getting the crew to tend six lettuce plants is not a problem," says Dr Wheeler. But a bigger project would require automation. Cameras could monitor plant colour and sensors could detect nutrient and water levels, as well as temperature and humidity. Adjustments could then be made when needed.

5 GARDENING GEAR

Just like on Earth, gardeners in space would need tools to plant seeds and harvest crops. But in a spacecraft, there's not much storage space for equipment. "In space, tools would be similar to the ones we have on Earth but custom-made for operating in a weightless environment," says Dr Wheeler. "They'd be miniaturised; they'd be low power."

SPACE CROPS



STRAWBERRIES

This delicious fruit has been grown in space before. Requiring less light to flower than many species, strawberries are ideal for growing inside a spacecraft with limited resources. They could be used as part of different treats for sweet-toothed astronauts.



SPINACH

A ready-to-eat crop that, along with radishes, tomatoes and spring onions, does not require a lot of tending. Growing plants and making fresh meals, rather than opening sachets of pre-prepared meals, would take a lot of time. So the more hands-off a crop is, the better.



SWEET POTATO

NASA studies have focused on staple crops that could form an important part of an astronaut's energy intake. Sweet potatoes make an ideal staple crop as they are loaded with energy and are not picky when it comes to growing conditions.



SOY BEANS

Soy beans could form part of many different meals, including scrambled egg-style tofu and a soy milk drink. Research shows that space radiation affects the quality of food made with soy beans, making tofu softer and milk taste slightly off. But this can be masked with another flavour.



LETTUCE

This, the staple of any good salad, has already been grown successfully in microgravity in chambers on the ISS. Along with other salad crops, it has the advantage of being ready to eat. The problem will be making enough of it to have a significant contribution to sustaining the astronauts.



WHEAT

This has been grown on the ISS. Processing makes it more of a challenge to eat in space, and its ratio of edible to inedible mass is low. But although it may be more effort than the likes of lettuce to process, astronauts on long missions will need wheat to make staples like bread and pasta.

KELLY OAKES is a space science journalist

SMARTY



ANTS



Compact satellites, faster plane boarding and quicker downloads – the humble ant has inspired all three. **Adam Hart** reveals what these six-legged marvels can teach us

TO LOOK INSIDE an ant nest is to contemplate an alien civilisation. The boiling mass of worker ants beneath an upturned stone is both strangely reminiscent of human society and strikingly different. There is an industry and organisation that fascinates us and a long line of myrmecophiles (or ant lovers) leads back all the way to King Solomon, who in fact advised to “go to the ant, consider her ways and be wise”. This was exactly the inspiration behind *Planet Ant*, a BBC Four programme showcasing what we know about the realm of ants, and what ants can teach us about the human world.

Like us, ants build structures, find food, defend their societies and manage waste, and – also like us – they must be well organised. For example, the leaf-cutting ants of *Planet Ant* have special waste disposal areas for storing hazardous waste and a team of ‘waste-disposal ants’ dedicated to keeping the nest clean. But ants achieve this familiar end result in a very different way to humans.

Human societies have centralised control. In other words, someone tells us what to do. Ants, on the other hand, have decentralised control and neither the queen nor any other ant directs work. Ant workers are the ultimate self-starters, following specific, but potentially flexible, rules in certain situations.

Chemical trails underpin much of this self-organisation. Foragers lay a mix of chemicals known as trail pheromone behind them as they walk. Other ants follow the trail and if they find food they reinforce it, laying more pheromone as they return to the nest. Stronger trails are more likely to be followed, so trails leading to food become progressively reinforced, while trails with no food at the end evaporate away.

This combination of positive feedback and evaporation produces an effective foraging system that is very good at finding the quickest routes to food. This simple guiding principle, and others like it, has provided some elegant solutions to the complex problems faced by engineers, computer scientists and businesses alike.

Could ants one day build micro-mechanical motors for us? Probably not, but they're clever in all sorts of other ways



GETTING YOUR DELIVERIES ON TIME

➔ WE'VE ALL WAITED for a package that didn't turn up on time. And it seems that ants do a better job of delivering their parcels – or more specifically leaves – than your postman does. In finding the quickest way to food, ants are solving a routing problem. Businesses that need to deliver products while minimising costs must also solve routing problems. Scientists have discovered that we can borrow the principles of ant pheromone trails to assist with our own 'foraging problems'.

The best known routing conundrum is the 'travelling salesman problem' (TSP). The TSP seeks to find the shortest route between a number of different points and this becomes progressively harder as the number of points increases. However, simulations using the principles of pheromone foraging in ants, an approach dubbed Ant Colony Optimisation, have been very successful in solving TSPs.

One example is Air Liquide, which supplies gas to a large number of customers across the USA, making this a particularly complex TSP. To solve it, the company uses a routing system based on Ant Colony Optimisation, with trucks laying 'virtual pheromone' standing in for ants. Computers run through the night to calculate the most efficient routing solution for the next day's deliveries, saving fuel and time.



A vast distribution centre resembles the high organisation of an ant colony – studying how the insects make their deliveries could help us make ours more efficiently

Leaf-cutter ants do what they do best: shifting leaves. But to do so effectively they lay down a network of pheromones secreted from their abdomens

“Scientists have discovered that we can borrow the principles of ant pheromone trails”

Ants are very good at getting in and out of confined spaces, something that will hopefully make the start of your holiday slightly less stressful

BOARDING YOUR PLANE QUICKER

FINDING A SEAT on your flight seems to take forever when you're stuck in a queue. So Southwest Airlines of the USA looked to ants for inspiration to speed things up. The airline allowed customers to choose seats as they boarded a plane, rather than assigning them a seat number in advance. But it wondered if the alternative was more efficient.

To test which was really the best boarding method, the company created a computer simulation that replaced humans trying to find a seat on a plane with ants. The virtual insects were given a simple set of rules, such as to find a seat when possible, to wait if the path was blocked, and to ask other ants to move if they were in the way. The ant-inspired simulation concluded that assigning seating beforehand was actually slower than giving passengers a choice on the aircraft.





The bustling swarm of an African safari ant migration; internet data could be sent quicker thanks to studies into the way ants forage for food

QUICKER COMPUTER NETWORKS

A FORAGING ANT colony has a network of trails along which it sends foraging ants to collect food and bring it back to the nest. By following simple rules the ants are able to use foraging trails to self-organise food collection.

But using this system is more than just following a trail of breadcrumbs. As well as finding food, the colony wants to ensure that it sends out the right number of foragers. If there are too many for the food available then the colony is wasting resources and risking lives. But too few means that the colony is not getting as much food as it could.

To solve this problem, researchers working on desert ants found that workers can use a very simple rule: the rate that workers leave the nest to find food depends on the rate that workers return to the nest with food. If there isn't much food out there, the return rate of successful foragers is low and

very few new foragers will leave, but a torrent of successful foragers signals a food-rich environment and the colony responds by sending out more workers.

The ants' foraging mechanism is almost identical to Transmission Control Protocol, or TCP – an algorithm used to avoid congestion on the internet. When a file is transferred it is broken into small packets and once each is received an acknowledgement (or ack) is sent back to the source. A high rate of acks shows that there is plenty of bandwidth and the transmission speed can be increased, much as a high rate of successful foragers returning to the nest means plentiful food.

Given that there are more than 11,000 species of ants that have evolved in many different ecological situations, researchers are keen to understand more about how they run their network operations. The hope is that the study of ant foraging networks will reveal other useful mechanisms that can inspire us in our own network management.

SMALLER SATELLITES

CUBESATS ARE MINIATURE satellites measuring just 10cm along each edge and are a relatively inexpensive way to do space research. Clyde Space, a Glasgow-based CubeSat manufacturer, has been investigating ant-inspired methods to build better satellites. With weight and space both at a premium, CubeSats need to be designed with the minimum amount of cabling. Just as ants use pheromones to find food, computer programs based on virtual ants laying virtual pheromones through a simulated CubeSat have created the most space-saving wiring solution.

Leave food out on a hot day and ants will be on it in minutes – an efficiency that scientists are trying to replicate



When you hear a fire alarm, hopefully you won't end up in a pile-up outside the building like this swarm of Harvester ants, which are, in fact, masters of organised chaos

SAFER CROWD CONTROL

VERY LARGE GROUPS of people in confined spaces can quickly turn into a life-threatening crush, especially if panic spreads. Constructing spaces with crowd safety built-in is an important part of modern architecture. Ant researchers studying Cuban leaf-cutting ants found that 'crowds' of ants contained in a space with two separate exits will tend to leave the space by both exits equally under normal conditions, but if a repellent chemical is added they will 'panic' and pile up around one exit, making it take longer to evacuate the area.

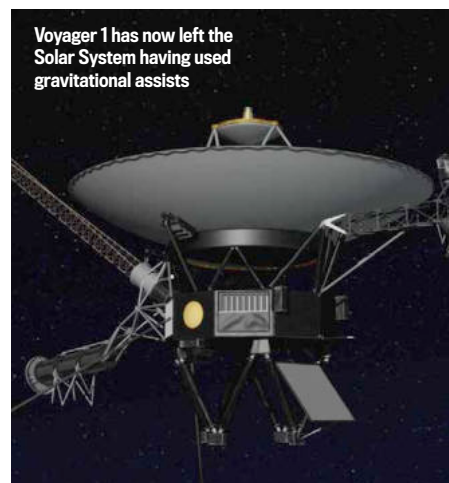
Similar panic-induced escape patterns have been found in theoretical simulations of human behaviour. Given this similarity, further investigation of the architecture of ant nests, and the ways in which different designs help ants move around within the nest could inspire human architects to come up with novel solutions for our own crowd control.





Australian jumping jack ants feed on a leaf; the way they chose their path to reach the food could be used to create super-efficient routes for spacecraft

“The ant-inspired approach has produced accurate trajectories far more rapidly”



Voyager 1 has now left the Solar System having used gravitational assists

FORGING FUEL-SAVING ROUTES THROUGH OUTER SPACE

➔ A SPACECRAFT CAN use the gravity of large bodies like planets to provide a ‘gravity assist’. By travelling on the right trajectory, the planet’s gravity increases the craft’s speed and changes its direction in such a way that, if you have done the mathematics correctly, it propels the craft towards its final destination. Gravity assists save on fuel and these celestial slingshots have been used to propel space probes like Voyager immense distances through space. Voyager 1 has travelled so far using this technique that it has now officially left the Solar System.

Although more complex than the traditional Earth-bound Travelling Salesman Problem, designing trajectories through space is still, at a fundamental level, a routing problem. However, to make use of gravity assists, the passage through space has to be combined with very accurate timing, which also makes this a scheduling issue. Researchers at the University of Strathclyde and the University of Glasgow have used the principles of pheromone foraging

trails to construct a modified Ant Colony Optimisation algorithm (set of instructions) that predicts routes through space. The algorithm removes the need to check all possible routes (a very time consuming process) and instead compiles the route incrementally, with each additional trajectory building on those the model has already ‘foraged’. Using this ant-inspired approach, they can predict the schedule and trajectories required to take advantage of multiple gravity assists far more rapidly than traditional methods.

Perhaps even the wise King Solomon couldn’t have predicted just how much we have come to learn from considering the ways of ants. ■

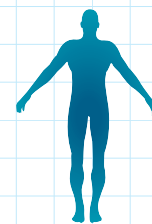
ADAM HART presents *Planet Ant* on BBC Four as part of the *Alien Nation* season. Adam has been studying ants for 15 years and is a fellow of the Royal Entomological Society.

Find out more



Don’t miss *Planet Ant* on 11 March at 9pm on BBC Four.

Body Science

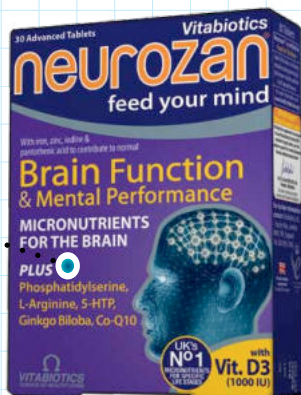


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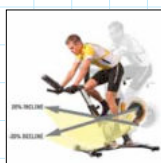
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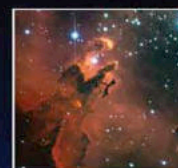


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Images (left to right)
Gamma Ray Burst (artists impression)
The Liverpool Telescope in La Palma
A Liverpool Telescope image of M16

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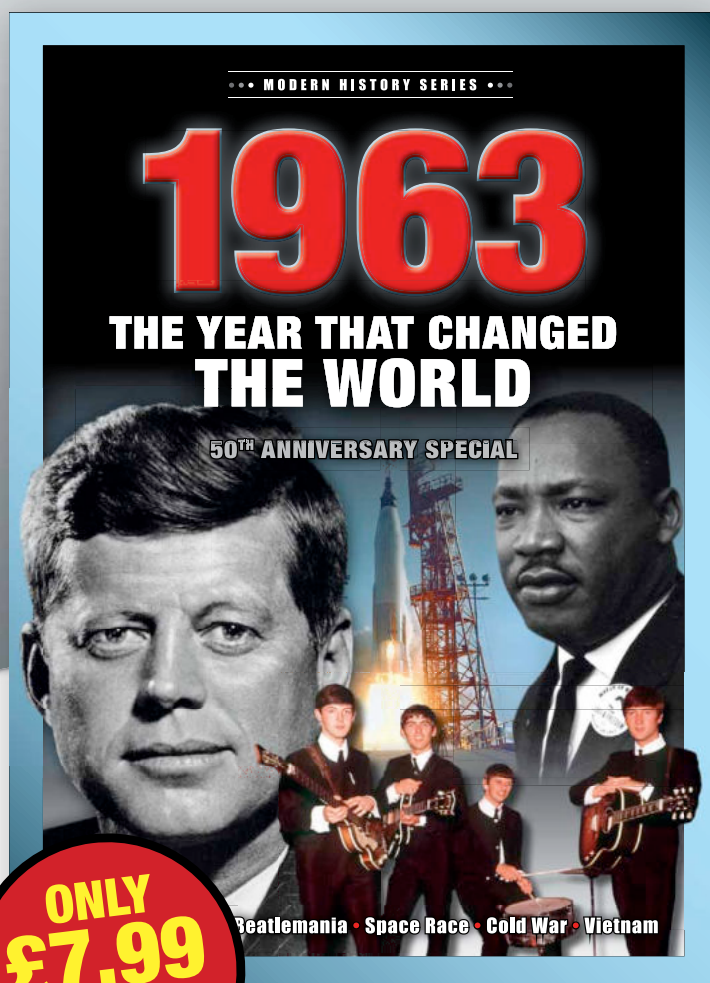
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THE FUTURE OF GADGETS

TECHHUB

EDITED BY **DANIEL BENNETT**

THIS MONTH

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ON THE HORIZON

VUZIX M100 SMART GLASSES

EVERY YEAR some 150,000 people descend upon the Consumer Electronics Show in Las Vegas. Attendees flock to Sin City from all over the world to see the launch of nearly 200,000 new products. Sadly, the reality is that only a few of these can truly be described as new. Most tend to be variations on a theme: a TV gains a few more inches or a camera offers a few more megapixels. But occasionally, there's something completely new, like the Vuzix M100 smart glasses.

Until now, Vuzix have simply built small displays into sunglasses. Having the screen sit close to your eyes means you can get a 'big screen experience' without actually needing the big screen. These rather bulky specs have appealed to a clutch of gamers and frequent flyers, but few others. The M100 Smart Glasses – perhaps inspired by Google's Project Glass – however, are a different beast altogether.

The asymmetric headset has one display, no bigger than a two pence piece, which is held in place about 8cm away

from your left eye. However, this headset isn't just for video playback, it's loaded with accelerometers, gyroscopes and a compass for head tracking, GPS for Sat-Nav and a 720p camera for recording video. It also has Bluetooth so it can mirror what's on your smartphone's screen and use its internet connection.

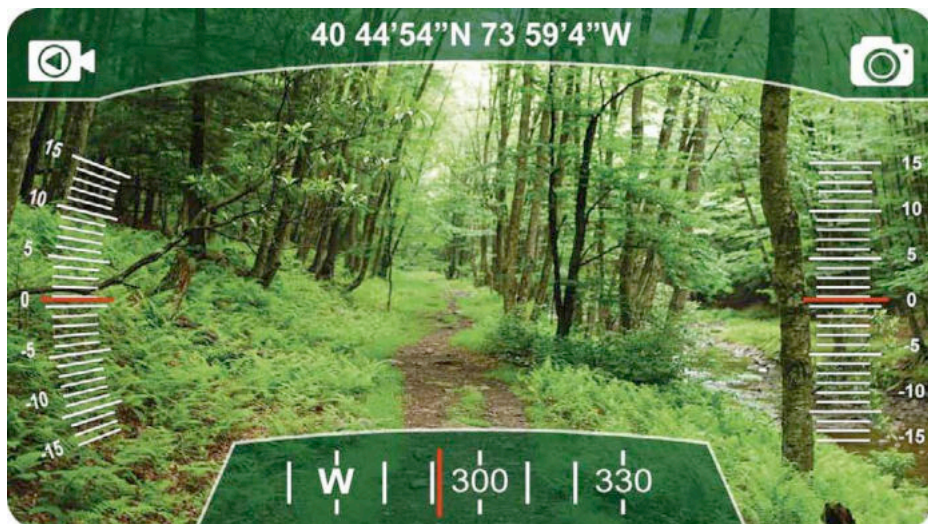
All of these features form the core ingredients for augmented reality – computer generated images are superimposed on a person's view of the real world. For example, if the smart glasses can track your position via

GPS, cross-reference it with any landmarks the camera can see and the position of your head, a Sat-Nav app could virtually draw the route ahead on the glasses.

Reminders could also spring into view when you pass a supermarket to buy milk; a game could insert virtual enemies into the real world; special offers could spring up when you walk past a restaurant. It's a vision of the future of the internet shared by both Vuzix and Google.

But while we wait for Google to finish its take on smart glasses called Project





It's a bit like *Terminator* vision, except that instead of hunting the leader of a future human resistance, you'll be using Vuzix's Smart Glasses to capture stunning views (top) and plot your route on country strolls



Glass, Vuzix has already put together a working prototype of the hardware that we were able to test for ourselves. At first, it certainly takes some getting used to.

While it's close to one eye, it's far from the other, which makes focusing on the screen a little tricky. We were assured that the final headset would be fully adjustable, allowing each user to find the visual 'sweet spot'.

As it stands, it mostly does what it says on the tin. We watched clips of *The Incredibles* played off the unit's hard drive while occasionally diverting our attention to what was on the show floor. The mirroring of your phone's handset appears to work well but it's difficult to see why you'd want to see your phone's screen on a headset and not the phone itself. And while the M100 has a sleek design that wouldn't look out of place in the next *Star Trek* film, wearing the

headset will make you stick out like a sore thumb.

So when it goes on sale later this year, who will want one? According to Pattie Maes, director of MIT's Fluid Interfaces group, this kind of device could be ideal for business: "The early adopters will be in a business context. Imagine how useful it could be for maintenance workers, warehouse operatives or stock checkers."

Smart software could use the device's camera to count the stock on the shelf, and then automatically show the user if there are more deliveries scheduled for that item. It might not set the world on fire at first, but with the right software and enough time smart glasses could shift not just how we interact with tech but the real world too.

DANIEL BENNETT is the *Focus* reviews editor

TECHOMETER



WHAT'S HOT

DYSON AIRBLADE TAP

The purveyor of fine vacuum cleaners is continuing its crusade to revolutionise public conveniences. Following on from the success of the Airblade dryer, its latest product marries a tap with a hand dryer. That might not get your heart racing, but the Airblade Tap boasts some impressive figures. Its motor spins at 90,000 RPM, a speed it reaches in just 0.7 seconds, to dry your hands in 12 seconds flat.

WHAT'S NOT

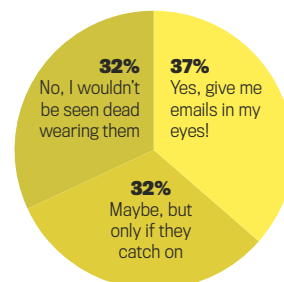
PASSWORDS

After some 250,000 Twitter accounts were hacked last month the social network is looking into a new 'hack-proof' system that doesn't rely on traditional passwords. Similarly, Google's latest smartphone offers facial recognition technology in place of less secure alphanumeric codes. With practically every phone and computer today carrying a camera, it could mean that passwords could soon become extinct.



READER POLL

Would you wear smart glasses?





EARLY ADOPTER BILL THOMPSON

'Granny - you have 15 seconds to comply'

My mid-fifties are approaching. If I live long enough to need personal care in addition to any medical attention, then it will rapidly get very expensive. Indeed, there is a serious political issue brewing around the financial level at which people should be expected to pay for their own care.

Perhaps, robots can come to the rescue. A mechanised carer isn't a new idea, but it seems as though these caring robots will need to come of age soon if we're to solve the problem of an ageing population.

We're already used to seeing robots in factories, and small domestic robots like the Roomba vacuum cleaner are reasonably mainstream. But extending their range of activities to cover putting an elderly parent to bed is going to take some serious effort.

We have seen a lot of research and development, but no real products. A lot of innovation is taking place in Japan, where massive shifts in people's assumptions about looking after elderly relatives coupled with an ageing population are creating a crisis in health care – one that could mirror what Europe will experience in the years to come.

There's Ri-Man, a humanoid robot that looks like a character from the children's show *In The Night Garden*, equipped with an array of sensors and motors that allow it to gently lift granny in its mechanical arms and carry her safely around her flat. Or the 1m-high yellow Wakamura that reminds patients to take their medicine and calls for help if something is wrong.



In Europe, the EU-funded CompanionAble Project has developed Hector, a robotic assistant for the elderly that links to a smart home to provide support. Like Wakamura, Hector doesn't have any arms, but can be used to store keys and medicine.

And in the US, former Microsoft executive Tandy Trower has formed a company called Hoaloha Robotics – the name is Hawaiian for 'caring companion' – offering 'human-centric technology'

to support older people. However, since it was formed in 2010 there's no sign that we will see viable products any time soon.

Part of the problem is that we're simply not accustomed to living and working among the sorts of robots we'd need to lift people into bed or do other domestic tasks, but that may be about to change.

At the end of last year Baxter robots were launched by Rethink Robotics. Baxter is designed to work in manufacturing environments alongside people instead of in fenced-off areas, separated from any humans as most robots are now.

Baxter could also go a long way to making us accustomed to having robots around us in our daily lives, and perhaps lay a path towards domestic robots and service robots that can sense humans around them, making the idea of the 'nursebot' a lot more feasible.

But in the end the acceptability of a nursebot is likely to be social. Will we ever be happy to hand granny over to a robot, no matter sophisticated it may be?

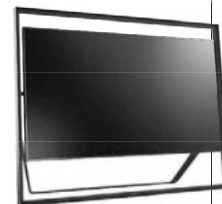
Bill Thompson contributes to news.bbc.co.uk and the BBC World Service

COMING SOON

3 MONTHS

SAMSUNG S9

If you've got £35,000 spare, then this 85-inch Ultra HD-TV (four times the resolution of 1080p) might be for you. The first Ultra HD broadcasts are likely to be the 2014 Rio World Cup matches, so you could always wait until then. Samsung.com



+ **Huawei Ascend Mate** This 6.1-inch smartphone stretches the definition of what you can still call a 'mobile' phone. It boasts new power management tech that extends battery life by 20 per cent. Huawei.com

+ **Razer Edge** A tablet designed specifically for gamers, the Edge can handle all the latest blockbusters a console can. Razer.com

6 MONTHS

OUYA

The Android-based games system is due to go on sale in June. Its creators hope the open source nature of the console will encourage developers to create cheap, original games so you won't need to spend a fortune to fund your gaming habit. Ouya.tv



+ **Lenovo IdeaCentre Horizon** This 27-inch, touchscreen desktop PC can be laid flat to become a tabletop computing surface. It's portable too, so you can carry it around like a giant iPad. Lenovo.com

+ **PS4** Sony has announced the successor to PlayStation 3, which could go on sale before Christmas. At the time of writing details were thin on the ground, but serious horsepower is guaranteed. Playstation.com

9 MONTHS

LG EA9800

OLED display technology means that TVs can now be curved, like this model from LG. LG says a concave screen means that the edges of the image are actually closer to your eye, reducing the distortion that occurs at the corners of the picture. We're undecided whether it's worthwhile, but either way it looks incredible. Lg.com



+ **PaperTab** A series of paper-thin, flexible displays that are connected to a central processor. It could be a whole new way of thinking about computing. Plasticlogic.com

+ **Apple iPhone 5s** Apple's next smartphone will appear in October. NFC, face-recognition technology and bigger storage capacity are all expected. Apple.com



TELL US WHAT YOU THINK!

Would you hand your granny over to a robot? Tell us what you think by emailing us at reply@sciencefocus.com



JUST LANDED

LASER QUEST

The ultimate in home cinema?
Jamie Carter tests a laser projector that creates a 100-inch cinema screen in your living room



LG HECTO LASER TV PROJECTOR
 LG.COM, \$10,000 (£6,319)

What is a laser projector?

It's a technology that uses laser diodes to beam out an image rather than traditional bulbs. To create a huge cinema screen in your home, projectors used to have to be far away from what they were projecting on to (at least 4m), with clear space in between. This isn't particularly convenient if you don't have a large living room. The LG HECTO, meanwhile, can create 100-inch images from only 56cm away, meaning you no longer have to have a cavernous space to enjoy a large screen.

How does it work?

Laser diodes aren't new in home entertainment products, being central to how a DVD player reads data from a disc, but here they're used as a light source. As well as being vastly more energy efficient than traditional xenon bulbs, the light produced from laser diodes – which passes through far fewer filters and optics – has a narrower wavelength.

It produces an image with more contrast, brightness, and finely graded colours.

What other benefits are there?

Though 'short-throw' projectors have been around for a few years, they've never got this close. They're famously tricky to set up and often produce wonky, disappointing images. The HECTO rectifies this by producing a crisp, perfectly aligned image with a huge 10,000,000:1 contrast ratio. That ought to ensure bright whites and inky blacks befitting a home cinema machine. Home cinema fans are also likely to get excited about HECTO's ultra short-throw skills, because it means you won't have to store a projector and AV equipment at the back of a room.

Can I watch TV on HECTO?

Yes – and a whole lot more. Although HECTO is a projector, it differs from anything else on sale by including a digital TV tuner, so you will be able to watch

Wonders Of Life on Freeview as well as attaching a DVD or Blu-ray player through one of its HDMI slots. It's meant for hi-def films and games since the laser engine is capable of Full HD 1080p video quality. It also includes Intel's WiDi software to wirelessly mirror what's on a laptop, PC or tablet, and it even has smart TV apps.

So it's like a smart TV?

A very smart TV. As well as hosting apps like BBC iPlayer, YouTube, Facebook, Lovefilm and Netflix, HECTO can stage big-screen Skype video calls. You also get LG's Magic Remote. This is a bit like Nintendo's Wii controller that offers pointer control and it has a microphone inside, too. Cue all kinds of voice commands, including searching the TV schedules for the title of a programme or even a particular actor.

LG's SmartShare feature is also on board, which allows playback of digital files stored on USB sticks and computers on the same home network.

Most smart TVs can already do this, but HECTO is the first such projection system – and it's all done within a great looking interface that uses live thumbnail images for each video file.

Should I buy one?

If you love home cinema, this should be a serious consideration. We were impressed by the straightness of the image and its colour and contrast, but – and it's a big one – the Full-HD pictures we saw weren't particularly sharp. Even high definition images blown up to this size are a bit of a stretch, which is probably why the TV and projector makers – including LG – are now making Ultra HD TVs with four times the resolution of 1080p. In the long term, laser TV will probably become a cheaper alternative to truly huge TVs.

Jamie Carter is editor of *Home Cinema Digest*


1

2

3

4

5

6

APPLIANCES OF SCIENCE

1 POWER BOX

If you've been disappointed by solar-powered tech so far, this heavyweight generator can store enough energy to power a chest freezer for a whole week or charge a tablet 120 times over. Of course to get that much electricity out of it in the first place, you'll need to leave it in the Sun for 20 straight hours first, or plug it into the wall for 16 hours. Perfect if you like to go camping with all your gadgets in tow. **Goal Zero Yeti 1250** goalzero.com, £1,500

2 CLOCK-WATCHING

Unlike most GPS sports watches, the Leikr actually shows you a map of your route like you'd see on a standard Sat-Nav. If you're flagging, you'll be able to see just how far you've got to go. Built by former Nokia engineers, it can create new routes on the fly while storing details such as how many calories you've burned, what your training targets are and how many routes you've run that fit in with those targets. **Leikr GPS watch** leikr.com, price TBC

3 HARD STORE

The HyperX Predator is a name more befitting of a stealth bomber than a data storage device. Nevertheless, that's exactly what Kingston has named its new thumb drive. But it has earned its bombastic title by being the world's largest flash drive, storing a whopping terabyte of data – that's around 6,000,000 books! It doesn't come cheap though. **Kingston HyperX Predator** Kingston.com, \$3,400 (£2,153) plus P&P

4 TICK TOCK

Mechanical watches don't cope very well with magnetic fields – a nuisance if you happen to work in a power station or a hospital. Of course, you could just buy a digital watch, but if you want to make a statement, this timepiece is made entirely out of non-ferrous materials. Its maker claims it's the only one like it you can wear standing next to the Large Hadron Collider. **Omega Co-Axial Calibre 8508** Omegawatches.com, price TBC

5 WEIGHT WATCHER

This new smart scale is the first to inform you of the quality of the air in your house, while telling you how much you weigh. It sends your data wirelessly to a website that will transform it into a handy chart. You can pair this with an activity monitor that records your steps taken and your pulse, to work out how much of a dent you're making in your weight-loss targets. **Withings Smart Body Analyser and Activity Tracker** withings.com, price TBC

6 PEDAL POWER

While it's unlikely that this bike will spend any time doing bunny hops on the Moon, the Moonlander is designed to provide traction on every surface on planet Earth. The fat tyres are 12cm wide and are filled to a low pressure to increase the surface area of the tyre in contact with the ground, providing more grip. This makes it ideal for cycling over snow, wet gravel and even sand. **Surly Moonlander** surlybikes.com, price TBC

DOES NOT COMPUTE!

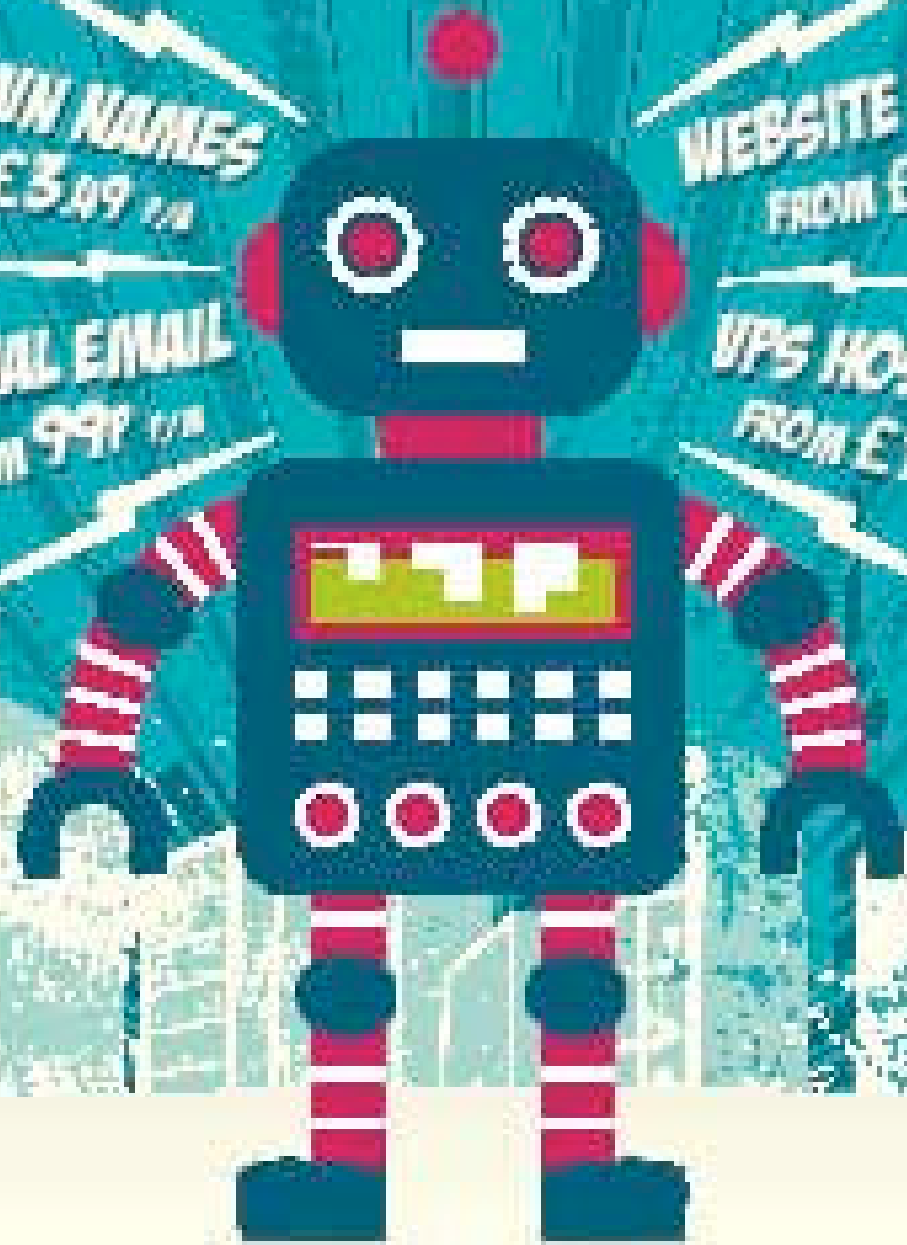
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ULTIMATE TEST

ROBOTS SUCK!



Still pushing your own vacuum cleaner around?
How very 20th century! **Russell Deeks** kicks back
and lets the latest robot models do the work

WILL A ROBOT VACUUM MAKE MY LIFE EASIER?

On the whole, yes. Obviously not all robot vacs are created equal, which is why we did some rigorous testing of their cleaning abilities that you can read about over the page. But both Neato and Roomba will give your floor a decent going-over, and it has to be said, putting your feet up while a robot does the housework is uniquely pleasing.

CAN I THROW AWAY MY OLD VACUUM CLEANER, THEN?

We'd advise against it. These vacs don't come with the brushes and crevice tools you get with normal vacuum cleaners, which does limit their abilities somewhat when it comes to those hard-to-reach spots. And of course, just like the Daleks, they're completely useless the minute they encounter a flight of stairs...

DO THE 'BOTS HAVE ANY DRAWBACKS?

Artificial intelligence (AI) only goes so far: these cleaners *won't* know when they've 'missed a bit' and *will* struggle with those awkward corners. They're best if you have large rooms and a minimalist approach to home décor. If you're living in a studio flat crammed full of furniture, they won't be much use to you.





Roomba



Neato



Neato



Roomba

THE CLUTTER TEST

→ WHAT WE DID:

We booby-trapped the floor with some random 'hazards' – a discarded newspaper, a stray slipper, a loop of speaker cable poking from under the stereo – to test the cleaners' AI and navigational abilities.

HOW THEY FARED:

The last time we tested robot vacuum cleaners we left one 'bot to clean a room and came back to find out it had spent the last three hours trying to mount a stray trainer. But that was three years ago, and judging by our two vacs' performance, AI and navigation

technology has improved since then. **Roomba** passed this test with flying colours: the stray stereo lead presented no problems, and it went over newspaper as though it wasn't there. As for the slipper, it dodged the heel end and clambered over the toe but there were no hold-ups. **Neato** did almost as well. The lead presented it with no difficulties and, though it did get stuck on the slipper a couple of times, on both occasions it managed to free itself. Our only slight grumble was that, in cleverly swerving to avoid the newspaper, it did miss a bit of floor behind it.

THE WALL TEST

WHAT WE DID:

We limited the cleaners to a 3m stretch of corridor, and put a 10cm strip of biscuit crumbs all along the skirting boards. We wanted to see how well the cleaners got into the edges.

HOW THEY FARED:

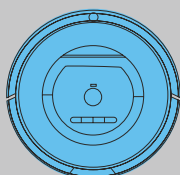
This was what a sports commentator might call an 'upset', because we were fully expecting **Neato** to triumph. Its flat-sided shape and no-nonsense, "I'm going in a straight line and you're not going to stop me" navigation – compared to the round-bodied **Roomba's** habit of zipping from A

to F then back to C – would surely make it a dead cert? But while **Roomba** did indeed bump about from one wall to the other seemingly at random, after the five minutes we'd allowed there were only a few crumbs left in the crevice formed by carpet and skirting board. **Neato**, on the other hand, found the wall, ploughed along it for less than two minutes, then announced it was finished. But lacking the **Roomba's** nifty extruding, rotating brushes, which get into awkward corners and sweep debris into the cleaner's path, it had left half the crumbs behind.

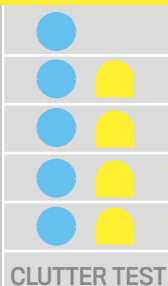
THE RESULTS

IN THE BATTLE OF THE VACUUM ROBOTS THERE CAN ONLY BE ONE WINNER...

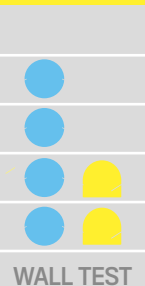
ROOMBA 780



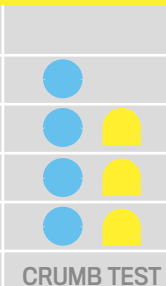
irobot.com, £579



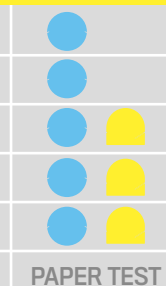
CLUTTER TEST



WALL TEST

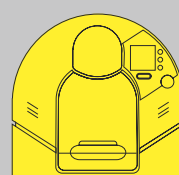


CRUMB TEST



PAPER TEST

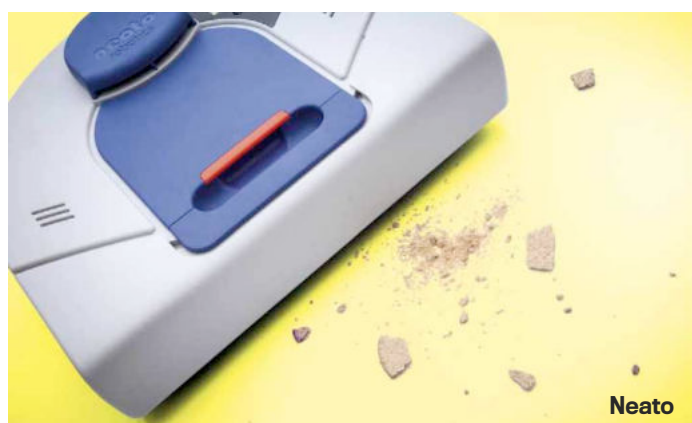
NEATO XV-25



neatorobotics.com, £399



Roomba



Neato



Neato



Roomba

THE CRUMB TEST

WHAT WE DID:

To test raw suction power, we scattered 150g of biscuit crumbs across a 4m² area of carpet. Each cleaner had five minutes – then we brushed up and weighed the remaining crumbs.

HOW THEY DID:

In many ways, this was the most important test of all. After all, no matter how clever a robot vac might be, no matter how effortlessly it avoids chair legs, no matter how sleekly designed it is, and no matter how cutely it returns itself to its charging station, if it fundamentally doesn't

suck the dirt and dust from your floor it's not worth having, is it? Well, we probably wouldn't go so far as to describe either robot vac as 'not worth having', but there was a clear winner here. **Neato** gave up after two minutes 15 seconds and announced it had finished, leaving two noticeable piles of crumbs, some scattered larger fragments and quite a lot of surface dust – we swept up 14g of crumbs afterwards. **Roomba**, on the other hand, took the full five minutes but by the end, there were virtually no visible crumbs and we only managed to sweep up 2g of biscuit dust.

THE PAPER TEST

WHAT WE DID:

Having heard robot vacs could struggle with bits of paper, we ripped up a page of newspaper and a man-size tissue into tiny pieces, scattered them across 4m² of carpet and let the vacs do their thing.

HOW THEY DID:

One of the chief grumbles in online store customer reviews and in forums, is that robot cleaners often fail to pick up larger bits of rubbish, like torn bits of paper. So, wanting to ensure both cleaners got a fair crack of the whip, we gave them as long as

they needed to do the job rather than imposing a time limit. That didn't make much difference to **Neato** – it did its usual trick of announcing it had finished and returning to its starting point after a couple of minutes. It did a pretty decent job, to be fair. It struggled a little with the largest newspaper fragments, leaving 11 behind, but all the annoying little scraps of tissue were gone. But again it was the **Roomba** that really impressed. Its crazy pillar-to-post navigation meant it took a while longer but at the end, only a couple of small scraps remained.



THE VERDICT

BASED ON TEST results alone, the Roomba 780 is a clear winner, but the Neato XV-25 does have its good points. Its shape makes it better at getting into some spaces than the Roomba (though the Roomba's brushes go a long way to balancing this out), and unlike the Roomba you can empty

it without picking it up, which may benefit elderly users. It's also considerably cheaper, and makes a jet engine-like noise on power-up that's really quite gratifying. The Roomba, however, offers better cleaning performance, is quieter, looks more stylish and comes with a remote control, so there's really only one winner for us.

RUSSELL DEEKS is a technology journalist

HOW DO WE KNOW?

HOW DISEASES SPREAD

BY WILLIAM BYNUM

The ancient Greeks attributed all illness to an imbalance of bile and phlegm, and it was hundreds of years before the true cause was discovered

THE REALISATION THAT many common diseases are caused by 'germs' was probably the most important discovery in the whole history of medicine. It brought about a new technology that was able both to prevent and, eventually, to treat these diseases. It also necessitated

new thinking about what disease is.

Germ theory emerged in the 19th Century, but it built on two notions that had earlier incarnations. First, germ theory separated the disease from the person suffering from the disease. Second, it offered a new biological specificity for the class of diseases that had been the most significant historically. These two ideas were fully appreciated only in the second half of the 19th Century.

Doctors traditionally viewed diseases as originating within the human body. The ancient Greek Hippocrates elaborated a theory of four body 'humours' that dominated Western medicine for two millennia. These humours (blood, bile, black bile and phlegm) were each produced

within the body, and their proper balance constituted health. If there was too much or too little of one or more of them, disease ensued, and the doctor's task was to restore the balance that was best for the individual patient.

This model was challenged by two doctors, Paracelsus (c.1494-1541) and JB van Helmont (1579-1644), who conceived disease as an external 'thing' (called an 'ens') which could attack any organ of the body. By separating the patient and the disease, they offered a new way of thinking about illness. But although each man had his followers, their ideas did not convince many doctors to abandon Hippocratic humoral principles.

This 'ens' remained poorly defined, but it opened the way for the disaggregation of person and disease. The second ultimate insight of germ theory, a new way of classifying disease (disease classification is called nosology), was also elaborated by a doctor with no knowledge of 'germs'. Thomas Sydenham (1624-89) is sometimes called the 'English

Hippocrates', because he provided careful descriptions of specific diseases. In a famous passage, he argued that the symptoms of disease are the same in a Socrates and a simpleton, and that diseases could be classified just like botanists classify plants, which also differ individually.

Sydenham didn't follow up this idea in any detail, but it offered a starting point for later doctors worrying about the names they gave to medical diagnoses. Why do we call this disease measles and that one smallpox?

RIVAL THEORIES

The diseases that the germ theory would eventually help explain and control were those that could often become epidemic, racing through a community or whole country. Plague, smallpox, typhus, scarlet fever and measles were among the scourges that decimated populations. Explaining them was a way to try to prevent their arising and spreading, and two main theories that attempted to do so had been long in contention.





Under ultraviolet light, bacteria show up as lighter shades of blue and purple - many of them could lead to disease

> IN A NUTSHELL

We've come a long way since the ancient Greek Hippocrates thought that our 'humours' had to be balanced to maintain health. Now, following a technological medical revolution, some diseases are able to be tightly controlled, while others remain as deadly as ever.

➔ One was miasma, which attributed their prevalence and spread to something in the air: the foul particles of rotting organic matter, such as food, faeces and the other pungent smells that permeated people's lives in earlier times. This theory accounted for the fact that many people who breathed the same air fell ill at roughly the same time, as an epidemic swept through the community. Removing foul wastes, sweeping streets and cleanliness were all appropriate responses, if this paradigm were the correct one.

Another theory was contagion, which recognised that a lot of diseases like smallpox seemed to be spread person to person, and consequently it was something engendered in the body and passed on to someone in the vicinity. Given this scenario, avoiding the sick and quarantine were in order. The bubonic plague, or Black Death, reminds us that neither theory commanded universal assent. During the repeated epidemics of plague that swept Europe from the 14th to the 17th centuries, both responses were repeatedly tried. Quarantine and

locking up victims and their families in their houses were combined with burning fires in the streets to cleanse the air, and holding nosegays if you were to come in contact with a victim.

Girolamo Fracastoro (c.1476-1553) put the contagionist case in his treatise of 1546, *de Contagione*. This, combined with his notion of 'seeds of disease', has led to some historians seeing him as a father of bacteriology. The reality is much more complex, but Fracastoro's writings did have influence. Having no microscope, he could not see the 'seeds' of which he

THE KEY DISCOVERY

How one man single-handedly solved the mystery of one of the biggest killers of the 19th Century – 'consumption', or what we now know as tuberculosis



Koch's work on tuberculosis made him a founding father of modern medicine

This 'key discovery' wasn't actually an experiment, but rather more than six months of solitary work by Robert Koch. During 1881-2, he tackled the leading cause of death in the 19th Century: consumption, or tuberculosis. Tuberculosis is quite unlike acute contagious diseases, which provided the model for early work in the field.

Most doctors thought it was an inherited disorder, attributing the familial incidence to bad heredity. The *tubercle bacillus* is slow-growing, and difficult to stain and cultivate. It was at least easy to grow in guinea pigs, which then developed tubercles in their lungs. Koch managed to find the right medium for the fastidious organism:

heat-coagulated sheep serum. He found that a combination of the dyes methylene blue and Bismarck brown stained it, making it visible in his microscope. In producing the disease in his laboratory animals, and recovering and growing it again, he fulfilled the criteria of what we still call 'Koch's Postulates'. Koch's redefinition

of tuberculosis changed how it was understood, justifying public health measures including building tuberculosis sanatoria, in which individuals with the bacillus in their sputum were isolated for long periods. There they were also treated with the largely ineffective therapies that remained in place until the antibiotic era of the 1940s.

wrote. Bacteria were finally visualised by Antoni van Leeuwenhoek (1632-1723), a Dutch draper and lens grinder who produced remarkable magnifications of many objects. As microscopes gradually improved in quality and reliability, many people saw these microscopic creatures and a few tentatively associated them with disease. But theirs were always minority opinions, and in the early 19th Century, miasmatic explanations of epidemic diseases still seemed to most doctors to provide the best fit.

The most feared 19th Century epidemic disease, cholera, could be fitted into either the miasma or contagion camp, but John Snow (1813-58), in brilliant investigations of the 1848 and 1854 London cholera epidemics, showed that cholera was spread through contaminated water, not through the air as miasmatis had it. He did house-to-house surveillance in the neighbourhood of a contaminated public well in Broad (now Broadwick) Street, Soho, and showed that this single well, into which raw sewage seeped, was the source of hundreds of cases.

A wider epidemiological survey looked at the incidence of cholera in the customers of two London water companies. It showed conclusively that the customers of the company selling unfiltered Thames water from downstream, after London's sewers had drained into it, were about 13 times more likely to come down with cholera than the customers of an upstream company which filtered its water. In many instances, customers of the two companies lived in the same streets, in identical housing and breathed the same air. Snow analysed the waters chemically and microscopically, and although he found nothing specific to incriminate, he showed that cholera was a disease which was spread by faeces-contaminated water, not foul air.

GERM THEORIES

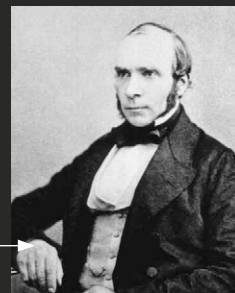
'Germ theory' was a long time coming, and there were many theories of the role of microorganisms in the causation of disease during the middle decades of the 19th Century. Our germ theory owes most to the work of the French chemist and physicist Louis Pasteur (1822-95). Pasteur came to microorganisms through his chemical work, and in the late

CAST OF CHARACTERS

The key historical figures whose research laid the foundations for modern medicine



Girolamo Fracastoro (c.1476-1553), an Italian physician, poet and natural philosopher, named the then-new disease 'syphilis' in a poem of 1530. His work on contagion (1546), with its notion of 'seeds of disease', is sometimes seen as a forerunner of modern germ theory.



John Snow (1813-1858) was a British anaesthetist and epidemiologist. He was a pioneer of inhalation anaesthesia, providing for Queen Victoria during the births of her last two children. His research on cholera reinforced his notion that it was not transmitted by miasma, but through contaminated water.



Louis Pasteur (1822-1895) was a French chemist and microbiologist. His studies of yeast, bacteria and viruses had a big impact on brewing and wine-making, milk safety ('Pasteurisation') and medicine. His was the first thorough notion of a germ theory of disease.



Joseph Lister (1827-1912) was a British surgeon and inventor of the 'antiseptic' system of surgery. Pasteur's research inspired Lister's use of carbolic acid dressings to disinfect surgical wounds (1867). Lister also did original research on bacteria, and his system was developed into 'aseptic' surgical practice.



Robert Koch (1843-1910) was a country GP when he elucidated the life cycle of the anthrax bacillus. This led the German bacteriologist to a research post in Berlin where he discovered the causative organisms of tuberculosis and cholera. He won the 1905 Nobel Prize for Medicine.

TIMELINE

The major landmarks in the history of science's quest to understand the nature and origin of diseases



Girolamo Fracastoro places the idea of contagion within a naturalistic framework, identifying several diseases that are **spread by specific contagia**. These include syphilis, rabies, measles and scabies.

1546

1676

Thomas Sydenham, in his *Medical Observations*, insists that **the symptoms of diseases** are so uniform that doctors should be able to classify them, just as botanists classify plants.



John Snow investigates patterns of infection during the London cholera epidemic, concluding that cholera is a **specific disease, transmitted via water** that has been contaminated by the faeces of those already suffering from the disease.

1854

1867

Joseph Lister announces his **'antiseptic' system** of surgery, in which his instruments, hands and dressing are soaked in carbolic acid to disinfect the wound site, reducing mortality from sepsis.



Robert Koch publishes the results of his experiments on the **tubercle bacillus**, showing that this greatest killer of the century is **caused by a bacterium**.

1882

➔ 1850s became convinced that yeast and other living organisms could do things that could not be achieved without life. Crucial in his own journey was his belief that living organisms could not spontaneously generate from non-living matter. In a series of famous experiments involving swan-necked flasks, which permitted air into his hay infusions but not the dust particles floating in the air, he convinced the scientific community that living organisms had an integrity and continuity that is the special province of biology. He investigated the role of these tiny organisms in the brewing of beer, the fermentation of wine and the souring of milk. His subsequent work on the diseases of silk worms and farm animals showed the importance of microorganisms in disease processes. This led to his vaccine against anthrax and eventually to his development of a biological treatment for rabies.

Pasteur was the most famous medical scientist of his time, but his methods of growing microorganisms were peculiar to him, and didn't work very well in the hands of others. His German rival Robert Koch (1843-1910), in contrast, was the quintessential bacteriologist. He perfected methods for growing pure colonies of bacteria, developed autoclaves for sterilising equipment, introduced photography to demonstrate what he had seen through his microscope, and identified some of the key disease-causing bacteria.

His work on the life cycle of the anthrax bacillus, showing that it had a spore form that could survive in the earth for a long time, put him on the scientific map. In 1882, he announced that he had identified a bacterial cause of tuberculosis, the west's most lethal disease during the period. The tubercle bacillus is slow-growing, difficult to culture, and causes a chronic disease (called consumption before Koch's work) that is totally unlike acute disorders such as typhus, cholera, smallpox and scarlet fever. Koch followed his research on tuberculosis with the identification, in early 1884, of the comma bacillus, which causes cholera.

Neither of Koch's major discoveries achieved instantaneous assent, but by the 1890s, numerous bacteria had been implicated in disease causation: these organisms satisfied what are still called Koch's Postulates. The bacteria were in locations in the body that showed

NEED TO KNOW

Key terms and concepts relating to germs and diseases

1 NOSOLOGY

The precise classification of diseases, whereby doctors know exactly the meaning of the diagnoses they give their patients. Germ theory offered a new precision, although many conditions (such as autism) are still difficult to define.

2 GERM

In medicine, any microorganism causing disease. Before 19th Century research, 'germs' were not necessarily living organisms, but could be poisons or bad smells in the atmosphere.

3 DISEASE SPECIFICITY

Historically, diseases were often thought of as highly variable, one disease easily transforming into another – for instance, one kind of fever becoming another during the course of an individual's illness or as a disease progressed through the community. Germ theory brought a specific cause to these infectious diseases.

4 CONTAGIA/MIASMATA

Contagia were the agents by which diseases were thought to spread from person to person, or via soiled clothes or bedding. A few diseases, for instance smallpox and syphilis, were also viewed as contagious. Others were associated with bad smells ('miasma' is the Greek word for pollution) that were believed to spread through the atmosphere.

they could be part of the disease; they could be isolated and grown in the laboratory; and they could be injected into experimental animals to produce the disease in question.

Showing that specific bacteria could and did cause specific diseases fulfilled the old dream of Paracelsus and van Helmont, and justified Sydenham's belief that the course of disease is sufficiently regular that a real classification was possible. It also alerted public health doctors to the fact that individual patterns of spread were the case: cholera through water, typhoid through food, tuberculosis through air-borne droplets and

A man with Ebola is comforted in by doctors in the Congo; there are still many deadly diseases that don't have a cure



sputum. Along the way, germ theory also opened up the technology and science to offer prevention through control of water and food supplies, isolation when required, and improvement of people's working and living conditions. It inspired Joseph Lister's (1827-1912) 'antiseptic' surgery, which developed into 'aseptic' surgery, sterilising equipment and trying to keep germs from wounds. It also provided the hope of vaccines (named by Pasteur in honour of Edward Jenner's 'vaccine' for smallpox, so-called because Jenner used the related cowpox virus – 'vacca' is Latin for cow).

In addition to anthrax and rabies, vaccines were developed with varying success for cholera, plague and typhoid. New understanding of the body's response to bacterial invasion led to therapies or immunisations for tetanus, whooping cough and diphtheria.

NEW AGENTS, NEW PROBLEMS

The triumph of the science and technology of germ theory by about 1900 turned out to be the beginning, not the end of the battle against diseases caused by living organisms. Rabies is caused by a virus, which is so small that Pasteur's microscope could not see it. New techniques and electron microscopes allowed these minute organisms to be identified, grown, studied and, in many cases,

prevented by vaccines. Measles, mumps, yellow fever, influenza and German measles have a viral cause and successful vaccines. But viruses like influenza are also capable of rapid change, making the battle between a vaccine and the new variant a constant one. Bacteria, too, have shown themselves to be wily, as natural selection favours those strains best able to withstand antibiotics and other therapies thrown at them.

Emerging viruses such as Ebola fever, Lassa fever, West Nile virus and HIV have also reminded us that there are still unpleasant surprises awaiting us out there. Plasmodia (which can cause malaria), rickettsiae (which causes typhus) and other infectious agents also pose threats. Even misshaped proteins called prions, implicated in Mad Cow Disease, pose health threats. These and a host of other modern health issues mean that many infectious diseases are still to be conquered. ■

William Bynum is Professor Emeritus of the History of Medicine, University College London, and the author of *A Little History Of Science*

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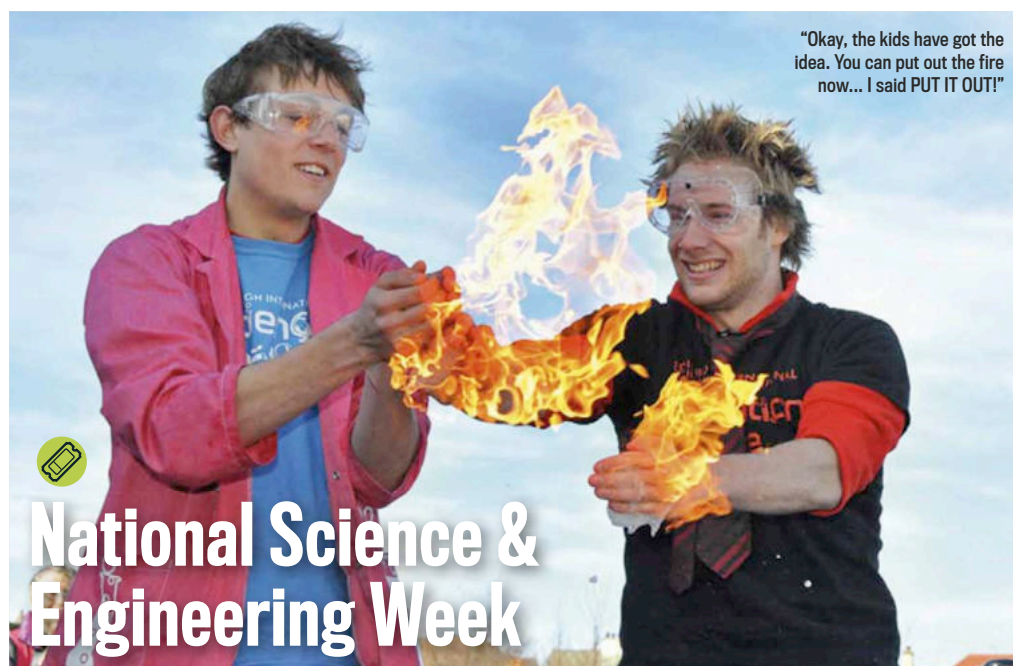
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PLAN YOUR MONTH AHEAD WITH OUR EXPERT GUIDE



PICK OF THE MONTH



National Science & Engineering Week

➔ BACK IN THE 13th Century, sailors feared a enormous sea creature called the Kraken, which was said to swallow whales and even entire ships whole. Tall story? Well, maybe not. An exhibition at the Scottish Fisheries Museum reveals that might be some science behind some of the old myths.

Science And Sea Monsters is just one of the events running as part of National Science & Engineering Week. It's an annual event and every year, the variety of activities gets wider and weirder.

Aimed at schools or families, there's plenty for adults too. In London, for example, the 200th birthday of pioneer epidemiologist John Snow will be celebrated by the London School of Hygiene & Tropical Medicine. You'll be pleased to hear that the exhibition includes a pop-up bar on the site of the cholera-spreading water pump on Soho's Broadwick Street (see www.johnsnow.org.uk for full details). Hopefully hygiene has improved since then...

In Yorkshire, you can hear a lecture on 'Volts, Amps & Ohms: Current Affairs in Revolutionary

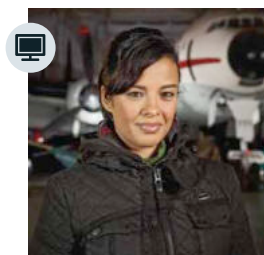
Europe', which promises to tell the stories of Messrs Volta, Ohm and Ampere. In Cambridge, they've organised an entire Science Festival with *Sherlock Holmes's* Benedict Cumberbatch as guest director. Even Alton Towers is adding science workshops to its school group bookings.

If you have children (or can borrow some), get to the Big Bang Fair on 16 and 17 March. Kids of all ages can enjoy dozens of shows and exhibits, including TV favourites Fran Scott and Greg Foot, zombies and robots. If you can't get to the main event at London's ExCel, there are regional Big Bang events too.

This year's Week has the theme 'Invention and Discovery' and covers 15-24 March (suggesting that a week in science is even longer than a week in politics).

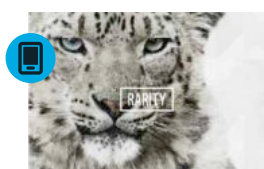
Find out what's on in your area at:
www.britishtscienceassociation.org/national-science-engineering-week

DON'T MISS!



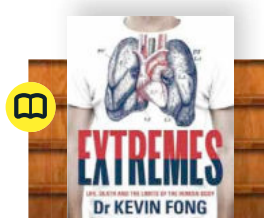
Horizon

The BBC's flagship science show returns, looking at inventions and where the next big ideas will come from in the 21st Century. **p114**



WWF Together

Learn about some of our most spectacular species with galleries and interactive 'toys'. **p116**



Extremes

Dr Kevin Fong explores the limits of medicine and the human body in his new book. **p118**



VISIT

EVENTS & EXHIBITIONS

WITH JHENI OSMAN

16-17 MARCH

Dunbar SciFest

Dunbar, £3 adult, £2 child, £10 family, £15 weekend family, <http://dunbarscifest.org.uk>



WITH STAGE SHOWS such as 'Elephant's Toothpaste', workshops on 'Zombie Science', drop-in sessions like 'Robokids', and films such as 'Quantum Circus', the festival looks set to be just as varied and popular as last year. Several Scottish universities will be there to discuss their current research, while sponsors EDF Energy and Community Windpower will be talking about the role of wind and wave power in Scotland's future.

UNTIL 13 APRIL

Science Live!

Various venues, every night at 7pm, tickets required, www.guinnessworldrecords.com/science-live



THIS IS LESS about who's the world's tallest woman or the length of the longest beard, and more about exploding nitrogen and firing human cannonballs - all in the name of science, of course. The Guinness World Records live tour is a celebration of the extremes of man's quest for knowledge, all demonstrated to dramatic effect on stage. There's also the chance to try and become a record-breaker yourself.

UNTIL 14 APRIL

Cambridge Science Festival

Locations throughout the city, most events are free, www.cam.ac.uk/sciencefestival



FROM TALKS SUITABLE for children to lectures that tax the grey cells, this festival has over 180 events to sink your teeth into. Highlights include recent Nobel Prize winner Sir John Gurdon discussing cloning, 2012 Christmas Lectures host Dr Peter Wothers unpicking the chemistry of the world around us and a pre-concert talk on how computer modelling is revealing why it's so tricky to play a string instrument.

JHENI OSMAN is a science writer and the author of *100 Ideas That Changed The World* (BBC Books, £9.99)



EDITOR'S CHOICE



Learn about centuries of discoveries at Cambridge's brand new Science Centre

NOW OPEN

Cambridge Science Centre

18 Jesus Lane, Cambridge, open 1-5pm weekdays, 10am-5pm weekends, half-term and holidays, £2.50 child, £3.50 adult, £10 family, pre-booking required for some events, www.cambridgesciencecentre.org



SAY THE WORD

'Cambridge', and what comes to mind? Punting? The Duke and Duchess? We're guessing it's more likely to be the university - in which case you'll be delighted to hear that a brand new science centre has opened slap bang in the heart of the city, with contributions from top researchers. It's a bit like London's Science Museum but with a local twist, showcasing past and current research from around Cambridge. You can learn about historic discoveries such

as how Newton revolutionised our understanding of light, or bring yourself up to speed with the latest breakthroughs from the university research labs. On a practical note, you can get hands-on with interactive exhibits, lively shows and inspiring workshops, find out the DNA secrets that make you into you, create electricity with your own muscle power, and get a taste of what it's like to make scientific discoveries by conducting your very own experiments. It beats punting any day of the week.

20 MARCH

Ig Nobel Tour

Hewlett Packard labs, Bristol,
www.improbable.com



THE IG NOBEL Prizes celebrate unusual science, with an annual awards ceremony at Harvard for research that first makes you laugh, and then gets you thinking. Take the co-discoverer of graphene, for example, who won an Ig Nobel for levitating a frog. This Bristol event is part of a UK tour, with other dates in London, Nottingham and Swansea and more to come – see the website for full details.

20 MARCH

Aping Mankind

Thinktank Theatre, Level 2, Millennium Point,
Birmingham, 7pm, free, www.thinktank.ac



DRAWING FROM HIS books, Prof Raymond Tallis (pictured) from the University of Manchester discusses whether neuroscience can really explain everything about human consciousness and behaviour. The poet, philosopher and former doctor, whose scientific specialism was the treatment of epilepsy and stroke victims, investigates and challenges the idea that 'we are our brains', suggesting that the real picture is far more complex.

21 MARCH

Botany Of A Holiday Hotspot

Natural History Museum, Tring, 7pm-8pm,
www.nhm.ac.uk/tring



LOUNGING ON A beach in Tenerife, you'd scarcely notice the remarkable biodiversity. But as home to more than 700 endemic plant species, the Canary Islands were a holiday mecca for botanists as far back as the 1600s. This talk, at the museum's Tring site in Hertfordshire, reveals the earliest collection of plants from the islands, and discusses why their biodiversity is so rich, and how it can be conserved.

23 MARCH - 7 APRIL

Edinburgh Science Festival

At locations around the city, prices vary,
www.sciencefestival.co.uk



NOT ONLY ARE there hundreds of events, many of them free, but they range from kids' activities to shows for over 18s. Talks cover everything from designer athletes to how testosterone fuelled the financial crisis and how we've struggled with our bulging waistlines since Roman times. And don't miss talks by science favourites – tweet the Universe with Marcus Chown, or investigate dreams with Richard Wiseman.

SPEAKER OF THE MONTH

24 MARCH


Dr Stephanie Snow

Wellcome Collection, London, 3pm-4pm, free,
www.wellcomecollection.org



Who is she?

Dr Snow is a medical historian at the University of Manchester, and author of the book *Blessed Days Of Anaesthesia*.

What's she talking about?

Anaesthetics. Until as recently as 160 years ago, no painkillers were available, yet surgery still took place. To celebrate the bicentenary of the epidemiology and anaesthetics pioneer, Dr John Snow, Stephanie talks about his work.

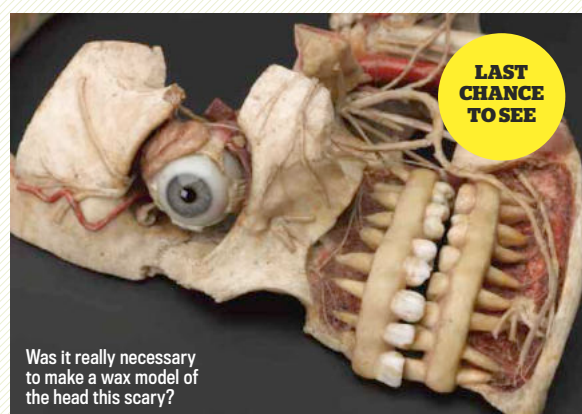
Is Dr Snow related to Dr John Snow?

John Snow is the great, great, great-uncle of Stephanie's husband. She only discovered the connection after researching Victorian public health and found that John Snow's portrait was in the family sitting room.

UNTIL 14 APRIL

Doctors, Dissection And Resurrection Men

Museum Of London, £9 adult, £7 concession/child, free to friends of
the museum, www.museumoflondon.org.uk



Was it really necessary
to make a wax model of
the head this scary?



IN THE EARLY 19th Century, to keep up with the demand for fresh meat upon which to practise dissection, the grim business of 'body snatching' thrived. Through human and animal remains, anatomical drawings and models, this exhibition reveals a murky underworld. And if that wasn't creepy enough, find out about the excavation that uncovered the graves of unclaimed deceased, dissected patients. Don't tell Damien Hirst – it might give him ideas.



WATCH

TV, DVD, BLU-RAY & ONLINE

WITH TIMANDRA HARKNESS

MARCH TBC

Newton: The Last Magician

BBC Two, TBC



HIS THEORY OF gravity got mankind onto the Moon, his calculus still lies at the heart of mathematics, and he dissected light itself. But Isaac Newton was also a man of his contradictory time, his beliefs straddling an occult interest in alchemy and the emerging scientific revolution. Reclusive and jealous, he nevertheless held public office as Master of the Royal Mint and in the Royal Society. Using material from Newton's own notebooks, this documentary brings to life the man as well as his ideas.

3 & 7 MARCH

The Sky At Night

BBC One/Four, 3/7 March, midnight/7.30pm

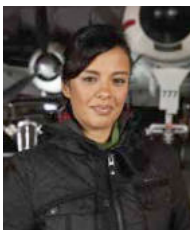


THIS MONTH, IMPRESSIONIST Jon Culshaw (pictured) dusts off his credentials as a keen amateur astronomer to join Chris Lintott and the team. They'll review the past winter of observing, and look forward to what the heavens have to offer in March. In the last month of dark skies before the spring equinox, you can look out for Saturn, Jupiter and a stray comet. That's assuming asteroid 2012 DA14 didn't hit us in February, of course. But if it had, you wouldn't be reading this, would you?

FROM 7 MARCH

Horizon

BBC Two, from 7 March



THE FLAGSHIP BBC science series is back. Looking inward, an episode on psychology and neuroscience will focus on creativity, scanning the brains of improvising jazz musicians. Liz Bonnin (pictured) asks where the new ideas for the 21st Century will come from. Dr Kevin Fong finds out how lives are saved by leaving less room for error, meeting the pilot who landed a plane on the Hudson River. And data itself comes under scrutiny, as everyone from astronomers to the LAPD taps into the torrent of information our world generates.

TIMANDRA HARKNESS is a stand-up comedian and presenter on BBC Worldwide's Head Squeeze YouTube channel.

The Challenger Space Shuttle had completed nine missions before exploding 73 seconds after its tenth launch



18 MARCH

The Challenger

BBC Two, 18 March

EDITOR'S CHOICE

➔ ON JANUARY 28TH 1986, Space Shuttle Challenger exploded 73 seconds after launch. NASA immediately launched an investigation, aiming to make sure whatever killed the seven people on board could never happen again. But the Presidential Commission convened to unravel the tragedy faced a labyrinth of vested interests and complex engineering.

One member of the Commission was equipped for such a task. A brilliant scientific mind, experience of the most politicised and secretive engineering projects, and complete independence from NASA gave him a head start. Richard Feynman was a charismatic, Nobel Prize-winning physicist who had worked on America's Manhattan Project to create the world's first atomic bomb.

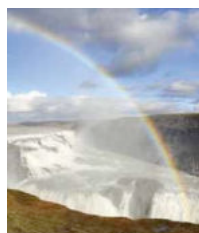
Feynman was determined to get to the bottom of the tragedy, against considerable odds. And it would take all his charm, intellect and tenacity to uncover the deep problems running through NASA and beyond, and to demand changes that would protect future missions.

In this original drama, commissioned by the BBC, actor William Hurt plays Richard Feynman. "This is the gripping story of a brilliant physicist's battle for scientific truth in the dark corridors of big government," says Kim Shillinglaw, BBC Commissioning Editor for Science and Natural History. "With an impressive cast, it promises to be a powerful factual drama," she adds. It's also a fitting celebration of Feynman's achievements, 25 years after his death.

FROM 11 MARCH

Voyage Of The Continents

Eden, starts 11 March, 7pm



IT'S LESS THAN a century since the theory of tectonics was accepted as explaining how the continents got where they are today – amazing, when you see the near-perfect fit of the African and South American coasts. This five-part series tells the story of the turbulent Earth. Entire plates collide, forcing mountain ranges to rise under pressure, while land sinks under ocean and volcanoes and earthquakes reveal the massive forces under our feet. Exciting? The Earth will definitely move for you.

14 MARCH

Naked And Marooned With Ed Stafford

Discovery HD, starts 14 March, 9pm



ED STAFFORD HAS managed to get washed up on a Fijian desert island. No food, no water, no tools and no clothes. So added to the perils of sharks, hunger and thirst, he'll be facing sunburn and chilly nights. Can he survive for 60 days, naked? Or will he spare a thought for the viewer and improvise some kind of garment?

27 MARCH

Is Breast Best? Cherry Healey Investigates

Really, 27 March, 8pm

Cherry Healey explores the trials of giving baby the white stuff



➔ **OFFICIAL HEALTH ADVICE**, backed by the World Health Organisation, is that babies should be fed only their mother's breast milk for the first six months of life. But in practice, that's not always easy. Presenter Cherry Healey found it painful and disruptive, and ultimately gave up, but she still feels guilty about failing. In this documentary, she meets lactivists who campaign for all mums to breast-feed, and guilt-free mothers who have happily used formula from birth. It's a journey of discovery.

DVD & BLU-RAY



The Universe in 3D: Catastrophes That Changed The Planets

History, £13.99, 3D Blu-ray

THE PLANETS MAY look well-behaved now, moving serenely in their orbits, but they've had a tempestuous past. Mars wasn't always a hot desert, Venus was temperate, and an impact left Mercury stripped to a barren core. Using NASA footage and CGI, watch the violent blows that disturbed Jupiter, formed Saturn's rings, and re-routed the orbits of the gas giants – and all in 3D.



Penguin - Spy In The Huddle

BBC, £16.25, DVD

IF YOU MISSED this BBC series in February, or if you now insist all your friends must see it, you can buy it on DVD. David Tennant narrates, but it's the fiendish cunning of concealed camera filming that deserves the applause here. Cameras were even concealed in robot penguins so lifelike they were accepted as members of the birds' community!



MythBusters Season 1

Discovery, £25, DVD

NO DODGY-LOOKING scientific claim is safe from Jamie Hyneman and Adam Savage. Will using your mobile phone at a petrol station cause an explosion? Will a penny dropped from a skyscraper embed itself in the pavement? From silicon breasts to chair-lifting helium balloons, the guys leave no prop unsmashed in their quest for the truth.

18 MARCH

Earth's Time Bombs

Eden, 18 March, 8pm



IF YOU THINK the volcano in Iceland caused trouble with its plane-grounding ash clouds, imagine one that pours its lava over an area the size of France. That's happened in the past, speeding the end of the dinosaurs. Now scientists say similar eruptions caused havoc in Europe only a few thousand years ago. It seems it's not just Iceland that needs to worry about angry volcanoes.

4 APRIL

Swimming With Monsters

Discovery, 4 April, 9pm



WE LOVE TO watch wildlife experts getting close to their subjects, and the more dangerous the better. Steve Backshall takes the genre one step further – into the ocean. He prepares by consulting behavioural scientists and top divers before swimming with sharks, doing aqualung with an anaconda and bathing with the hippopotamus, Africa's deadliest animal. Is he out of his depth?



LISTEN

BBC RADIO PROGRAMMES
WITH TIMANDRA HARKNESS

MARCH TBC

Mind Changers

BBC Radio 4, March TBC

PSYCHOLOGY IS A young science, and many of the ideas applied today were only developed in the 20th Century. Claudia Hammond discovers some of the pioneers and their legacies, including Maslow (whose 'hierarchy of needs' pops up in sociology and even management speak) and Anna Freud, pioneer of child psychology.

MARCH TBC

What If We Could All Speak To Joi Ito?

BBC World Service, March TBC

THE HEAD OF MIT's Future Media Lab, Ito will give a lecture, then answer questions on what the internet-powered world of the future might be like. "We look for unexplored spaces," he says. "And our key metrics for defining a good project are uniqueness, impact and magic." If anybody is in a position to outline a vision that's imaginative and technologically ambitious, it's the man from MIT. Part of an ongoing 'What If...?' season.

16 MARCH

What If We Could All Live In Silicon Valley?

BBC World Service, starts 16 March

JOURNALIST ALASTAIR Leithead visits the part of California that has filed more technology patents in the last 10 years than anywhere else

on Earth. Many businesses that now dominate international markets were born here. What technological marvels are next to come from Silicon Valley?

25 MARCH

What If Africa Was The New Hub Of Global Science?

BBC World Service, from 25 March

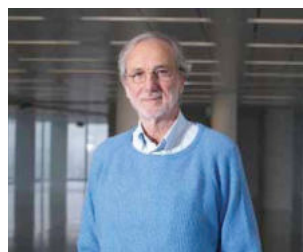
MAKERERE UNIVERSITY, near Kampala in Uganda, is East Africa's oldest. And for a week in March, it's also the site of a science festival that will be broadcast live on the BBC World Service. Scientists from the continent and beyond will debate the future of African research.

14 APRIL

Piano's Music Boxes

BBC Radio 3, 14 April, 7.45pm

THE SHARD, SPARKLING over London, is the celebrity building of the moment. But its architect Renzo Piano also designs more intimate structures. As a child, he aspired to be a musician, which would have been a good career choice considering his name. This documentary explores the relationship between sound and buildings, and asks if architecture shapes how we relate to one another.

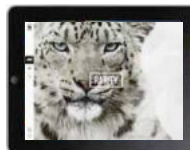


Musical inspiration: architect Renzo Piano



TOUCH

SMARTPHONE & TABLET APPS
WITH CHRISTOPHER PHIN



WWF Together

iPad
World Wildlife Fund, free

THIS IS A truly wonderful app that cleverly uses the iPad's tech to help you understand the wonder and majesty of some of our most spectacular species. For each of the animals – giant pandas, snow leopards, marine turtles and more – there are galleries and fun facts, but the real delight is some of the storytelling 'toys'. Nudge ice floes out of the way and chop down a panda's bamboo to reveal messages, stay as still as a polar bear hunting, and even simulate how much better a tiger's vision is than yours. A joy!



Powers Of Minus Ten - Bone

iPhone, iPod Touch, iPad
Green-Eye Visualization, free

THIS APP IS a fun way to explore your bones. You can zoom closer and closer to understand what's happening at the micro level. Once you're in as far as you can go, you're exploring the atoms in the DNA, with the calibration scale at the bottom reading 300 picometres (that's 300 trillionths of a metre). And on the way you've learned about ribosomes, osteoblasts (cells that secrete bone) and more, in an interactive 3D model. It's certainly not bone dry (ahem).



isosceles

iPhone, iPod Touch, iPad
Base 12 Innovations, £1.99

IF YOU'RE STUDYING or teaching geometry, this is a handy tool. Once you've added points, you can draw lines between them and create circles, pentagons and other shapes. Best of all, it stays live and smart, so you can use points of bisection to make new arcs. You can get info on objects too – though we wish it was easier to be precise about drawing regular shapes at specific sizes. There's a simpler, free version too, so you can try it before unlocking features such as iCloud sync and an isometric mode.

CHRISTOPHER PHIN is the editor of *MacFormat* magazine



PLAY

CONSOLE & COMPUTER GAMES

WITH NEON KELLY



Don't Starve

PC; Klei Entertainment; £11.99

DON'T STARVE CLOSELY resembles what might happen if the ghost of Jules Verne were hired to produce a Ray Mears survival show, with Edward Lear serving as the art director. As a stranded scientist, your task is to survive for as long as possible in a strange and hostile land, which means crafting your own tools, foraging for food and building fires when night falls. There are shades of *Minecraft* here, but *Don't Starve* has clearer objectives – though you should expect to die swiftly, and often.



Kentucky Route Zero

PC; Cardboard Computer; \$7 for one episode or \$25 for all five

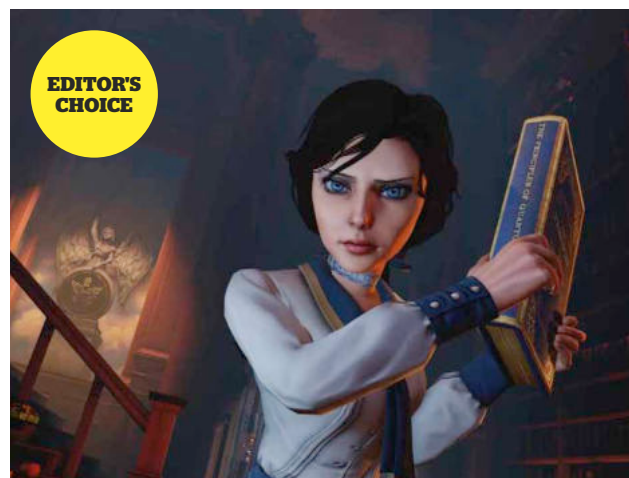
LAST YEAR *THE Walking Dead* proved episodic gaming could work, and now we have *Kentucky Route Zero* to further champion the format. This is a strange but beautiful take on point-and-click adventuring, an existential tale of a lost courier who discovers a secret underground highway. It's a pensive affair with a classy, minimalist art style and a beautiful soundtrack – a combination that should ensure its place as one of 2013's most discussed indie releases.



Gears Of War: Judgement

Xbox 360; Microsoft Studios; £39.99

GRAB YOUR GUN, overdose on testosterone and hide behind a waist-high wall, because the duck-and-cover shooter *Gears Of War* is back. This is actually a prequel to the first three games in the series, focusing on Damon Baird – a sardonic supporting character from the previous titles. The core action remains largely unchanged, but it's as glossy and frenetic as ever. The big change is that the game can now throw more enemies your way at any given time. If you're a fan of the series, that's probably all you need to hear.



EDITOR'S CHOICE

Hitting baddies over the head with hefty books on quantum mechanics is all very well... the only trouble is, you *didn't* hit them over the head with it at the same time

BioShock Infinite

PC, PS3, Xbox 360; 2K Games; £44.99



behind the ideas of its forbear. *Infinite* represents an effort to create something bold and new, but to retain the lightning-in-a-bottle brilliance that made the first game so memorable.

This is no simple task, and for all its bold direction there are still clear echoes of the original. *Infinite* may be divorced from the setting and narratives of the previous games, but you're still running around a bizarre, nightmarish city, battling lunatics with the help of magic spells. All the same, the recipe for this unconventional first-person shooter works – largely thanks to the fact that the game is packed with moments that will make your heart thump.

Columbia is a vividly imagined carnival of violence and insanity, a lurid landscape of blimps, towering propaganda and rollercoaster-like rails that offer a vertigo-inducing means to travel around town, and the action is louder and fiercer than in the first two games. But it's Elizabeth who steals the limelight: she's your companion, charge and comrade-in-arms, a vulnerable young girl who might just be the most dangerous thing in Columbia. She's an inspired character that you won't forget in a hurry – and the same can be said for *BioShock Infinite* as a whole.

➔ THE YEAR IS 1912 and our hero, Booker DeWitt, is a man with a problem. He's a former Pinkerton detective with skeletons in his closet and a hefty pile of gambling debts. To clear his accounts, DeWitt must travel to the city of Columbia and rescue a mysterious young woman named Elizabeth. But there are complications: Elizabeth has strange, fearsome powers that she can't fully control, while Columbia is a flying city – a hovering metropolis that has severed all ties with the USA and floated off in search of independence.

Meanwhile, Ken Levine has a different problem. As the creative lead behind *BioShock*, the defining game of 2007, he now has to oversee the birth of a worthy successor. The direct sequel in 2010 was a solid effort, but one that largely hid



READ

THE LATEST SCIENCE BOOKS REVIEWED

H Hardback **P** Paperback

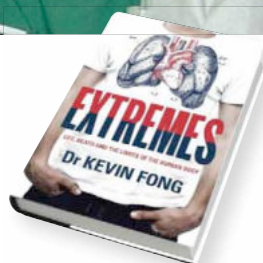


Anna Bågenholm (second left) with her fellow skiing friends; her heart stopped for over three hours following an accident

Extremes Life, Death And The Limits Of The Human Body

Dr Kevin Fong

Hodder & Stoughton **H** £20



DR KEVIN FONG is a consultant in anaesthesia and intensive care medicine at University College, London. He is also an expert in space medicine, having trained and worked with NASA. His background makes him particularly well suited to writing a book about the limits of the human body, which he does with considerable skill and detail.

What I enjoyed most about this book was the weaving together of his own biography and the stories he tells about the humans who have operated at the extremes. These might be the extremes of cold, or the ability offered divers to stay underwater for what seems like impossibly long periods of time. The book is especially poignant when he writes about his own experience as a young doctor having to deal with human bodies that have been savaged to the point of death.

I was particularly interested in his accounts of those who have recovered from near death as a result of exposure

to cold, since this is an area of research that I have covered in documentaries, most recently in relationship to military medicine. Kevin tells the remarkable story of Anna Bågenholm, who became wedged under ice following a skiing accident. Her core body temperature dropped below 14°C and her heart stopped. In fact by the time her rescuers finally got her to hospital, her heart had been stopped for more than three hours. You would have expected her to be brain dead after such a long period, yet she made a remarkable recovery and was able to return to work.

Stories like this have encouraged research into the use of cooling in a number of therapeutic situations, including on the battlefield. This is an excellent book that makes you appreciate our species' remarkable resilience.



MICHAEL MOSLEY is a writer, doctor and BBC science presenter

MEET THE AUTHOR



Kevin Fong

What's the book about?

Really it's about exploration in its broadest sense, and how over the last century science and technology have allowed us to look within the human body but also to look out and extend our reach into space. It also ended up being a very personal story about the conflict that I've always felt in my own life between my work as a doctor and my work with NASA. On the one hand, there's the very practical job of delivering medicine but on the other hand, there's this utterly esoteric idea of exploring the Universe.

Which part of the book did you most enjoy writing?

There are an awful lot of stories in medicine that as doctors we know almost as legends, so it was really enjoyable digging down into those stories and finding out the detail. When you do that, they become even more incredible.

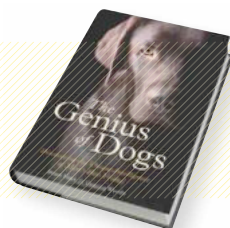
What was the most surprising thing you learnt?

All of the stuff about breath holding continues to amaze me. When you talk to respiratory physiologists about why we can hold our breath, and what determines the point at which we have to take a breath, it turns out that no one's really sure – it's a bit of a mystery. It's gobsmacking to me that the longest breath hold for people diving in tropical waters is over 11 minutes. That seems crazy because if you do the sums as a physiologist, it just doesn't look doable – no one should be able to survive that, let alone swim down to a great depth and then back up again.



MORE ON THE PODCAST

Listen to the full interview on the podcast at sciencefocus.com/podcasts



The Genius Of Dogs

Discovering The Unique Intelligence Of Man's Best Friend

Brian Hare and Vanessa Woods

Oneworld **H** £16

BRIAN HARE MADE his name as one of the world's leading anthropologists, but has recently turned his attention to the study of dogs. In 11 chapters he reveals, with his journalist wife Vanessa Woods, that this is a much longer-standing interest of his.

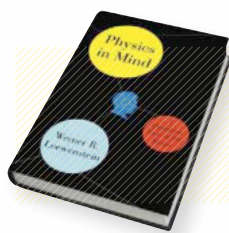
It condenses an enormous amount of current thinking on the subject within the context of a personal story. For example, he details a visit to a group in Siberia that did fundamental work on the genetics of domestication, as well as his experience with his own dogs. The use of notes throughout allows you to cross-check the data, without detracting from the flow of a text that had me laughing in places.

They also make the science understandable. In particular, they do an excellent job of tackling the often misrepresented topics of 'comparative intelligence' and the nature of perceived 'breed differences' in areas like agility.

While I may not agree with their interpretation of the ability of dogs to 'fast-map' like children, they point out that such disagreements are the life-blood of science. It's exactly this sort of debate that is shedding light on canine intelligence.



DANIEL MILLS is a Professor of Veterinary Behavioural Medicine at Lincoln University



Physics In Mind

A Quantum View Of The Brain

Werner Loewenstein

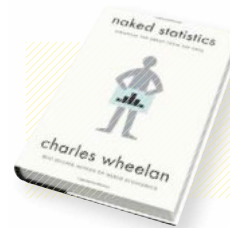
Basic Books **H** £17.99

I BEGAN READING this book with some suspicion, because its subtitle, *A Quantum View Of The Brain*, inevitably sets alarm bells ringing that this would be yet another half-baked attempt at combining quantum mechanics and consciousness. On the other hand, its author, the eminent biophysicist Werner Loewenstein, is a hugely respected academic and research scientist. So, I decided that if anyone were going to make headway into this baffling subject it should be him.

After a wide-ranging introduction on subjects like the arrows of time, entropy, information theory and molecular biology, Loewenstein gets down to business. In fact, while he does indeed steer the reader inexorably towards the climactic yet tentative suggestion that our brains are essentially quantum computers, the journey to that final and controversial idea is an epic one. This is not an easy read, but it is certainly worth the effort; Loewenstein brings in new research from both quantum information theory and neuroscience, and while the subject matter is often complex, the writing style is light and engaging.



PROF JIM AL-KHALILI is the author of *Paradox* and a BBC presenter



Naked Statistics

Stripping The Dread From The Data

Charles Wheelan

WW Norton **H** £18.99

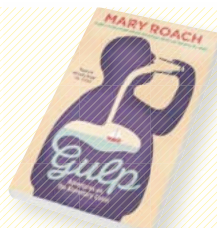
WHO IS THE greatest baseball player? How many people support the Occupy movement? Can job stress kill you? *Naked Statistics* sets out to explain the tools needed to answer such questions.

Each chapter focuses on one topic, using real life scenarios to outline the main ideas. This approach often works well – such as when potential problems with data are illustrated with tales of hidden drug trials and unfair polls – but some sections struggle to be both entertaining and rigorous. The anecdotes can be too brief to form a good story and the facts too scattered to be a useful reference. The chapter on correlation, for example, opens with an intriguing question: how does Netflix suggest new films to its customers? But the narrative is soon interrupted by calculations that seem out of place in an otherwise intuitive explanation.

Despite a few weak points, however, the book covers a good range of statistical concepts. In a world driven by data, uses – and abuses – of statistics are ever increasing. For non-specialists wanting to understand why, this book is not a bad place to start.



ADAM KUCHARSKI has a PhD in Maths and is an award-winning science writer



Gulp

Adventures On The Alimentary Canal

Mary Roach

Oneworld **P** £11.99

HAVING PREVIOUSLY TACKLED sex and death in her books, Mary Roach turns her attention to the bit that comes in between: digestion. Subtitled *Adventures On The Alimentary Canal*, the pace is as meandering as a boating holiday. But don't worry, the digressions are the best bit: penguins with refrigerated stomachs; snakes that belch flammable gas, the largest amount of fruit cake you can eat at a sitting...

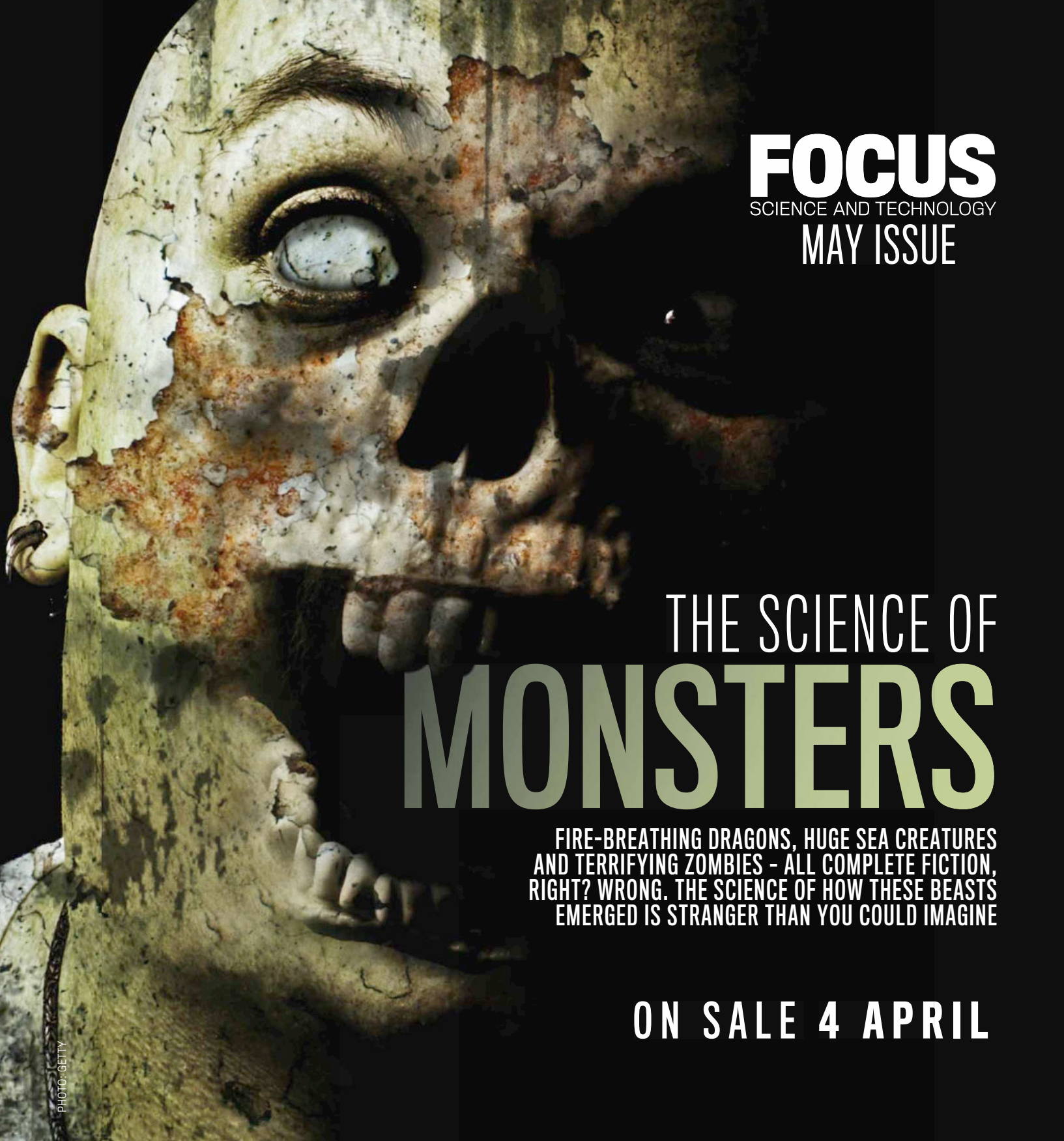
Mary Roach is often compared to Bill Bryson. But whereas Bryson hovers anonymously above the narrative, Roach likes to get personally involved. She visits the labs of gastroenterologists and chats

to them about their work, while sniffing inside jars and putting electrodes on her tongue. The mannerisms and appearance of each researcher are sketched for us along the way. These are funny, but occasionally feel irrelevant.

Nevertheless this is a wonderful read, with insight and anecdotes that make for great dinner party discussions or an absorbing read on the toilet. Which is appropriate enough.



LUIS VILLAZON is the author of *How Crows Reach The Ground*



FOCUS
SCIENCE AND TECHNOLOGY
MAY ISSUE

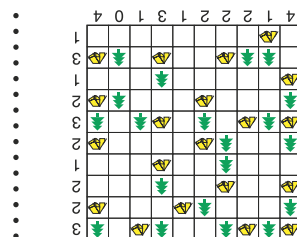
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SOLUTION
No cheating! Don't look at
this until you've attempted
the puzzle on p127



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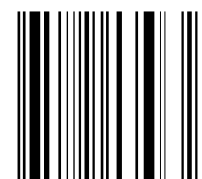


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THE BOOK REVIEW



A selection of great new books for your delectation

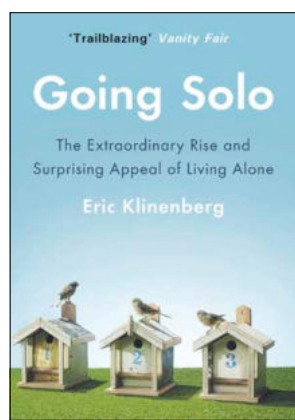
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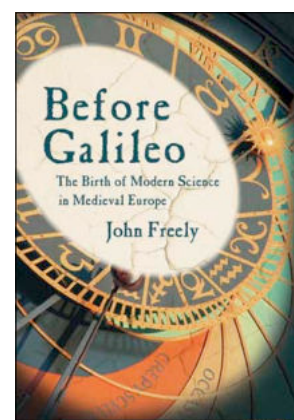
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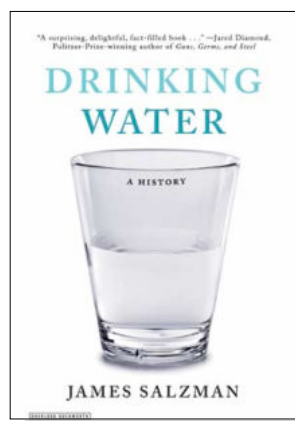
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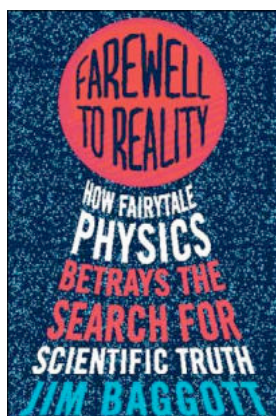
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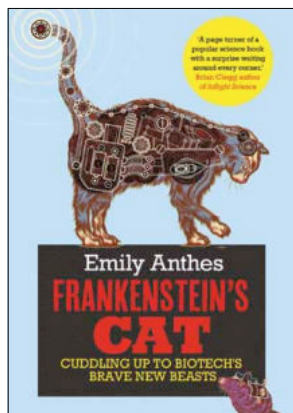


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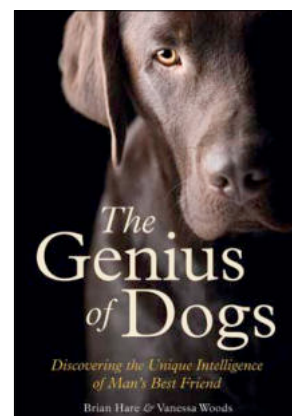


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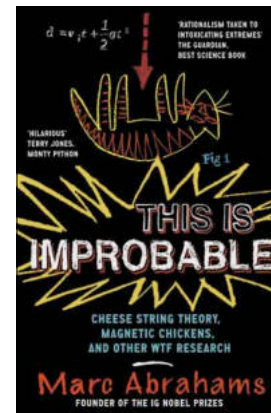


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Ian Edwards
OF HARROGATE

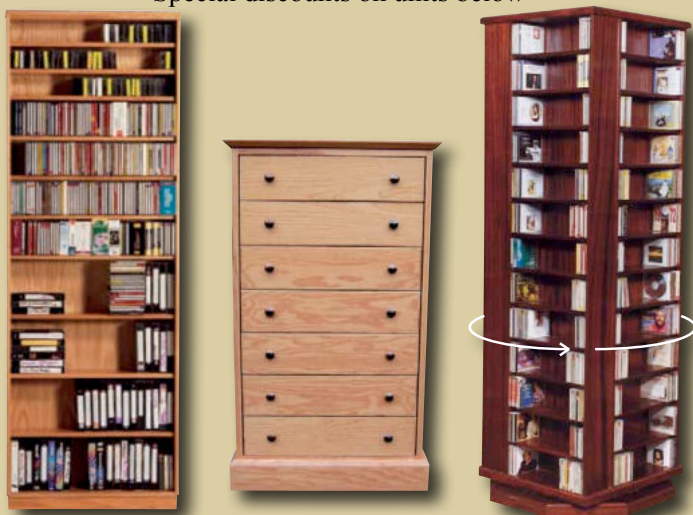
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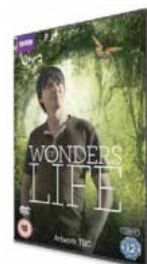


Supposing airmail regulations permitted only THREE stamps on an envelope. Which four different denominations should be issued (in whole pence) so that any total value from 1p to 24p could be sent attached?

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The first five correct entries win a copy of *Wonders Of Life* on DVD (BBC. £20).

Post your entry, marked 'Prize Puzzle 253', to: *Focus*, PO Box 501, Leicester, LE94 0AA, to arrive by 5pm on 4 April 2013. We regret that we cannot accept email entries for this competition. See sciencefocus.com/winners for a list of previous winners and solutions.

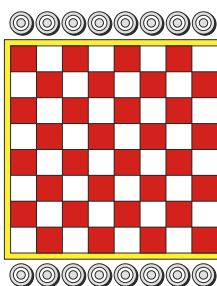


See bottom of p120 for terms and conditions. Congratulations to Andrew Holmes (Northumberland), Colin McLean (Edinburgh), Peter Haworth (Bristol), Alan Smith (Middlesex) and Matthew Waelan (Sheffield) who all answered January's Prize Puzzle to each win a copy of *Richard Hammond's Miracles Of Nature* on DVD

Q1
In what context can
 $XXXXXX/XXXXX = 278$?

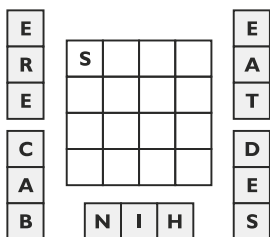
Q2 Due to their different Head and Tail designs, most coins do not give a 50/50 result. How can any coin be tossed to give a true 50/50 probability?

Q3 Place these 16 draughts into different squares so that there is a maximum of two draughts on any row, column or ANY diagonal (not just the main diagonals).



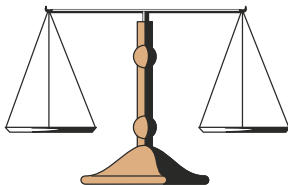
Q4
If Pawn = 4, Knight = 8, King = 8, Bishop = 13 and Rook = 14, what is the value of Queen?

Q5
Enter the pieces into the grid so that a 4x4 word square is formed.

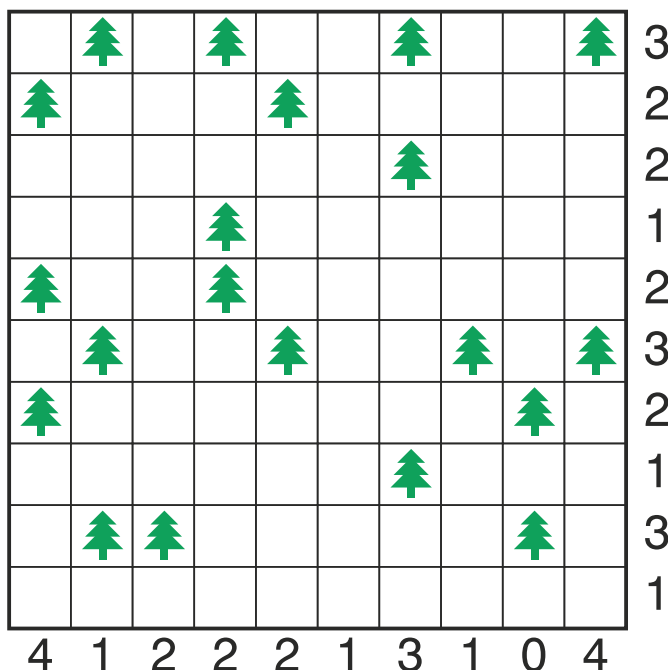


Q6
Place these words in a recurring sequence: COIN, SUSPECT, MINT, PHRASE, MAKE, QUESTION.

Q7
Using this accurate balance, a 5g weight and a 2g weight, how can you split 100g of sand into 18g and 82g piles in three weighings?



Q8 Place tents in the empty squares so that the number of tents in each row and column matches the numbers shown. Every tent must be immediately next to a tree (horizontally or vertically). One tent per square only. Tents are never adjacent to each other – not even diagonally.



SOLUTIONS

(Q5) Turn the NIH piece upside-down to form SHIN, CEDE, AREA, BEST across and SCAB, HERE, IDES, NEAT down.
(Q6) Make a mint, mint a coin, coin a phrase, phrase a question, question a suspect.
(Q7) One method: split the 100g on each pan into 50g/50g piles. Split one 50g again into 25g/25g. Then use both weights on one pan to subtract 7g from one of the 25g piles, giving 18g (and 82g remaining). (Q8) See illustration on page 112.

(Q4) 23 – the maximum number of possible moves it could make in a possible.

QUICK QUIZ

How much do you know about bones?

Q1

How many bones are there in the typical adult human body?

- a) 206
- b) 256
- c) 306

Q2

Which of these is not a type of cell found in bones?

- a) Osteoblasts
- b) Osteoplasts
- c) Osteoclasts

Q3

Which tiny bone in the ear is also known as the anvil?

- a) Malleus
- b) Incus
- c) Stapes

Q4

What is the longest bone in the human body?

- a) Fibula
- b) Tibia
- c) Femur

Q5

Which set of bones is the remnant of a vestigial tail?

- a) Os coxae
- b) Lumbar vertebrae
- c) Coccyx

Q6

A typical human ribcage consists of how many ribs?

- a) 12
- b) 24
- c) 36

Q7

What's the scientific name for toe and finger bones?

- a) Phalanges
- b) Tralanges
- c) Spalanges

ANSWERS:

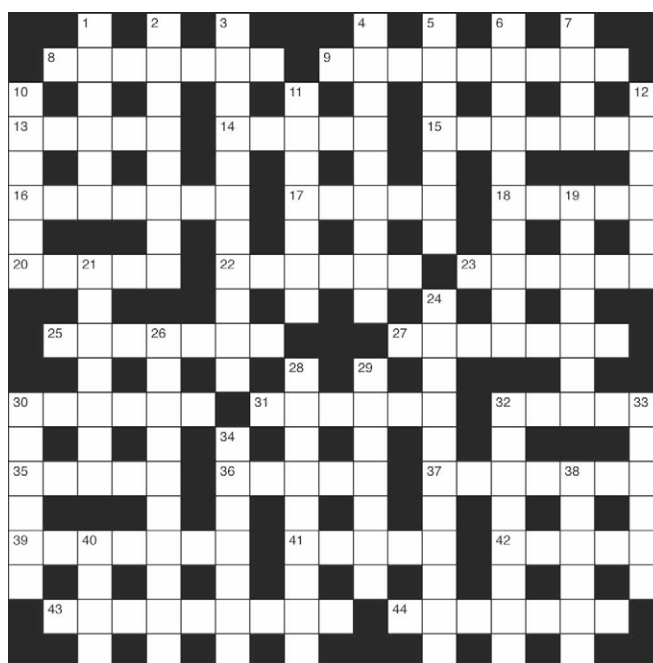
1a, 2b, 3b, 4c, 5c, 6b, 7a

YOU ARE:

- 0-3 Bone idle
- 4-5 Close to the bone
- 6-7 Bone-shakingly brilliant

FOCUS CROSSWORD No 149

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ACROSS

- 8 Expose around a beam (4,3)
- 9 Inapt dose affects both ends (9)
- 13 A rota devised for vital supplier (5)
- 14 The French queen has sulphur as a source of light (5)
- 15 Conservative party turned left concerning vault (7)
- 16 Nocturnal creature has worn lab out (4,3)
- 17 I would sing first when it's damp (5)
- 18 Joint dismissal (5)
- 20 Old game confused last character (5)
- 22 Terribly mundane, having lost top chaperon (6)
- 23 Terrace endlessly suffered bomb damage (6)
- 25 Complaint when yours truly gets bad sales (7)
- 27 Having lost weight, being solvent (7)
- 30 Old politician has energy and time but is excused (6)
- 31 Old relic from ship wrapped in metal sheet (6)
- 32 Covering a chicken (5)
- 35 African has time to get an engine (5)
- 36 Alright for a Greek character to have an animal (5)
- 37 Reveals confusion in quite a few (7)
- 39 Interconnected group finds employment on trawler (7)
- 41 Shoot a bird (5)
- 42 Engineers transport puzzle (5)
- 43 Remedy is neat - get strange immunisation (9)
- 44 Frenchman worked longer to find hybrid (7)

DOWN

- 1 Tree has space to the right of enormous wolf (6)
- 2 Soldier turned lob to a curve (8)
- 3 More content with ball, playing an organ (4,7)
- 4 Habituation to tune miner composed (9)
- 5 Olympic committee proposal about drug being a dangerous chemical (7)
- 6 Ponder holy construction that has many faces (10)
- 7 The excitement of added lemon (4)
- 10 Graduate rings doctor first for panda's diet (6)
- 11 Is old husband still finding lines of rainfall? (7)
- 12 Inferior fellow starts at the plant (6)
- 19 Assault in a cell (7)
- 21 Fundamental substance that provides heat (7)
- 24 Troll chose to perform with European steroid (11)
- 26 Policeman spent coins very fast (10)
- 28 Using soap, I must find an alkali metal (9)
- 29 Sprain treated with one pain-killer (7)
- 30 Travelling in mere fur (6)
- 32 Changing reel gave strategic advantage (8)
- 33 Enjoy a pickle (6)
- 34 Allow to reserve initial pamphlet (7)
- 38 Flexible game (6)
- 40 Vehicle or its fuel supply (4)

SOLUTION TO CROSSWORD No 146

Graham Mattock, Bill Manghan, Brian Duncan, MN Wesley and Roberta McCutcheon solved issue 250's puzzle and each receive a copy of *The Amazing Story Of Quantum Mechanics*.



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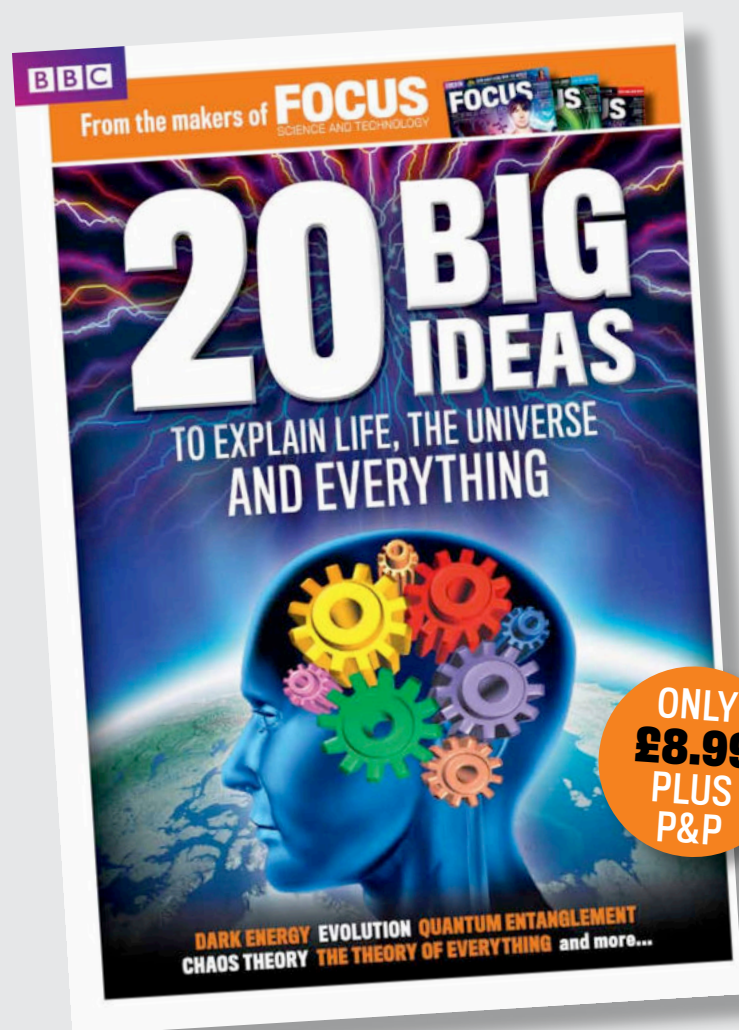
EMAIL

Post entries to *Focus*, April 2013 Crossword, PO Box 501, Leicester, LE94 0AA or email a scan of the completed crossword or a list of answers to april2013@focuscomps.co.uk by 5pm on 4 April 2013. Entrants must supply name, address and phone number. By entering, participants agree to be bound by the terms and conditions, printed in full on page 120. Immediate Media, publisher of *Focus*, may contact you with details of our products and services or to undertake research. Please write 'Do Not Contact' on your email or postal entry if you do not want to receive such information by post or phone. Please write your email address on your postal entry if you would like to receive such information by email.

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INTO THE FUTURE

STEPHEN BAXTER

HUMANS TODAY BELONG to a single species. From the poles to the equator, we all share the same DNA and can all breed with each other, which is the biologist's definition of a species. And we humans, *Homo sapiens*, are the only species in our genus, *Homo*. A genus is a class of related species, and it's actually quite unusual for a genus to contain only one species. The genus *Canis*, for example, contains several species of dogs, wolves and jackals.

We once shared the Earth with many *Homo* cousins, including the Neanderthals. *Homo neanderthalensis* inhabited Europe until some 30,000 years ago, and it has become clear in recent years that populations of other species survived until even more recent times, such as the 'hobbits' of Indonesia, *Homo floresiensis*, who may have survived until 12,000 years ago. By comparison, modern humans are thought to have emerged 100,000 years ago.

And we may not be unique in the future. We can think of many ways humanity might bifurcate into subspecies. We may differentiate ourselves consciously, through genetic engineering or cyborg technology, for example. If we plant colonies in space or on other worlds, again with time we may bifurcate; the isolation of a small group from a wider population is a classic cause of speciation, the emergence of a new species. Perhaps there will be humans adapted to zero gravity, or the austere climate of a terraformed Mars.

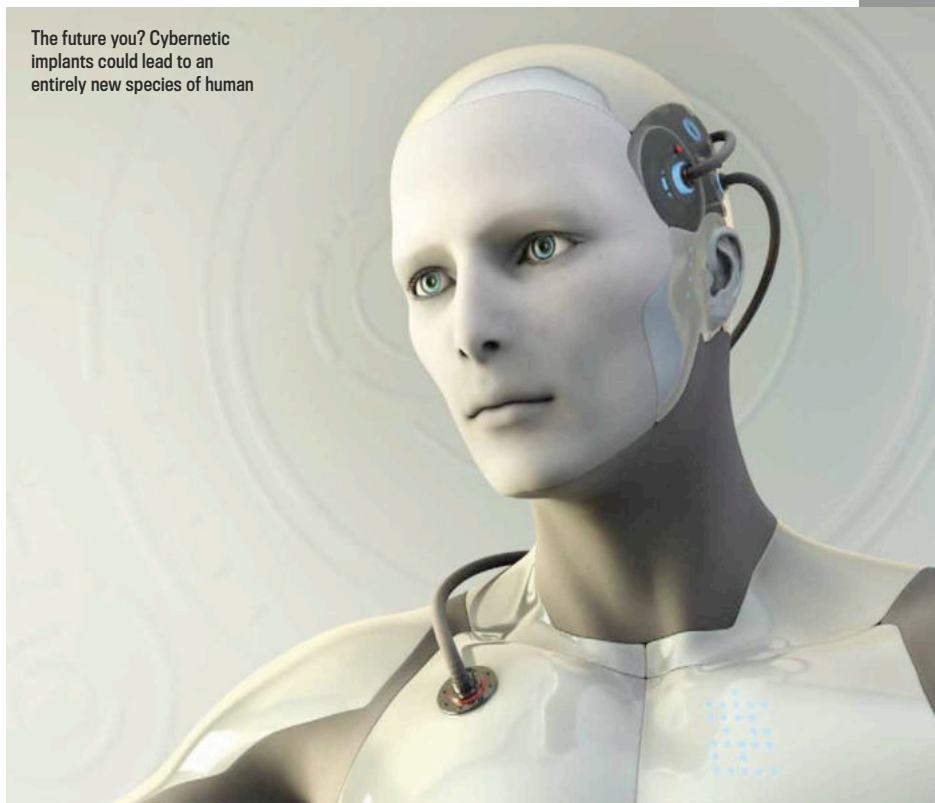
What would a world that was once again full of different kinds of human be like? One result we can probably predict with confidence is war.

This is a perception that dates at least as far back as HG Wells. Wells, who lived through the First World War, argued passionately for an end to war between humans, but he seemed to believe that conflict between species was inevitable. In his story *The Grisly Folk*, published in 1921, Wells describes contact between modern humans and Neanderthals.

The Neanderthal is our closest relative but in Wells' story it seems monstrous: 'The grisly thing... was hunchbacked and very big and low, a grey hairy wolf-like monster'. Contact soon leads to a one-sided conflict: 'For the [Neanderthals], [contact with humans] was the beginning of an incessant war that could end only in extermination... the two races were intolerable to each other.'

Why intolerable? Because 'they both wanted the caves and the banks by the rivers where the big flints were got. They fought over the dead mammoths that had been bogged in the marshes, and over

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the reindeer stags that had been killed in the rutting season.' This was not war, in our sense. This was a Darwinian conflict, between two species competing for the same ecological niche.

Wells had studied evolution under Huxley, Darwin's follower, and understood natural selection very well. Darwin himself noted that the most intense competition is between species that are most alike, because they compete for the same resources. In *On The Origin Of Species* (1859) he wrote: 'As species of the same genus have usually, though by no means invariably, some similarity in habits and constitution, and always in structure, the struggle will generally be more severe between species of the same genus, when they come into competition with each other, than between species of distinct genera.' This was what Wells imagined causing conflict between modern humans and Neanderthals: they were too similar to coexist.

In the future, it's to be hoped that sufficiently intelligent species will be able to rise above Darwinian imperatives. But otherwise, if our genetically engineered or space-adapted descendants are superior

to us, next time it may be we 'vanilla' humans who play the role of the Neanderthals, pushed to the wall of extinction by the ferocious competition of our smarter cousins. ■

STEPHEN BAXTER is a science fiction writer whose books include the *Destiny's Child* series and *The Science Of Avatar*

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